

RAPID INJECTION MOLDING Journal

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The Protomold Company, Inc.



Breakthroughs

Finding your way over, under, around
or through the obstacles you face.

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Catching the Breaks

We're looking, in this issue of the *Journal*, at breakthroughs, seminal ideas that propel technology into new areas and sometimes in entirely unexpected directions. The question is, what exactly is a "breakthrough?" We are such a curiosity-driven species and so given to tinkering that it might seem that the rate of exploration and the development would be constant.

By its nature, a barrier becomes a place where ideas, both good and bad, are tested.

The very term, breakthrough, provides some clues. Imagine a wall around a fortified town. Besieging soldiers pile up near the wall (though presumably far enough away to avoid the boiling oil) until the wall is breached at some point. Then, the waiting army gravitates toward that point, pours through the gap, and spreads out into the city to loot and pillage and otherwise earn their daily rations.

This analogy tells us something about the flow of information around an obstacle. By its nature, a barrier becomes a place where ideas, both good and bad, are tested. (This explains why, in many instances, the same problem may be

solved almost simultaneously in several places.) Concepts from seemingly unrelated fields may come together in classic examples of "lateral thinking." In other words, a barrier becomes a magnet for creative thought. In the case of the besieged city, soldiers may be of little use as engineers come into play finding ways under (tunneling), over (rolling towers or catapults), or through (rams) the wall.

At Protomold, we've benefited from externally developed breakthroughs like distributed data processing and the World Wide Web in building and expanding our operation. We've taken

advantage of more modest developments in specific fields—3D CAD software and CNC machining—incorporating them into our process. Combining those resources with hard work and creative thought, we've engineered a few breakthroughs of our own (see related story on page 5).

We designed a unique automated process joining 3D CAD modeling and CNC milling of aluminum injection molds. We've automated the evaluation of 3D CAD models for moldability and interactive online production quotes. By combining and expanding existing technologies, we've slashed both the cost and the time required for making molds. And in doing so, we've filled the gap between slow, expensive traditional injection molding and fast-but-limited rapid prototyping. We are actively continuing to expand our capabilities in this area and, in what may prove to be another breakthrough, are now applying our subtractive process to rapid prototyping, a field previously dominated by additive processes.

In a perfect example of the potential influence of breakthrough technologies, we are serving innovators in a variety of fields. Like most businesses, they must deal with demanding markets, aggressive competitors, globalization, and a variety of technical challenges. I'd like to think that the flexibility we provide helps them find ways over, under, around, or through the obstacles they face.



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Stair-stepping into the Future

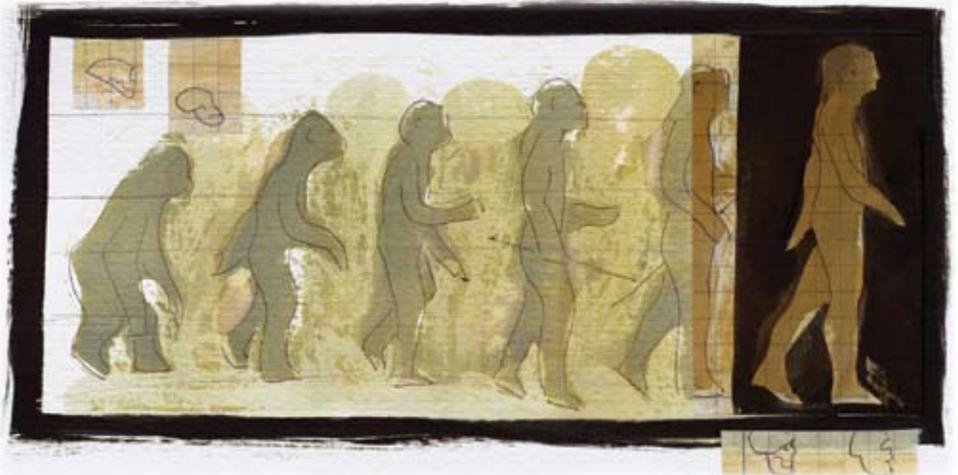
What's that rumbling? It's the sound of progress. As the earth's tectonic plates move over one another, friction causes them to briefly "stick" in one place until increasing pressure breaks them loose. With the pressure released, the plates jump forward, stick in a new place, and the cycle repeats. The term "briefly" may refer to periods of years, so the process may be unnoticeable to those of us who aren't seismologists, but when the plates move, we all notice the resulting earthquake.

Evolutionists now theorize that a similar pattern appears in the development of species. They call it "punctuated equilibrium," and it describes the alternation of periods of relative species stability with periods of rapid change. One example might be the "breakthrough" emergence

"...when the plates move, we all notice the resulting earthquake."

of aquatic life onto land. With a whole new environment to develop into, the ensuing development of species would have been explosive.

A similar pattern governs technical process. Control of fire, extraction of metal, the steam engine—each was a breakthrough that opened a world of possibilities. And while the developments following each of these breakthroughs have been valuable, they represent relatively flat periods of consolidation compared to the breakthrough itself. Like Shakespeare says of true love in *A Midsummer Night's Dream*, the course of technological change never did run smooth.



In plastics, the introduction of celluloid as a replacement for wood, bone, and ivory was the inaugural event. What followed was a rush of exploration into materials and applications that has changed the world. The breakthrough was the realization that we could engineer materials. The result was a process of guided trial-and-error in which dead-ends were abandoned while successes became parents to new lines of development. The resemblance to biological evolution is striking.

Digital computers were the breakthrough in information processing. Crude as it was, room-size ENIAC and its tube-based cousins were the giant step up to the IT plateau we've been exploring for the last half-century. We process gigabytes, store petabytes, and generate graphics that put reality to shame—we produce models in the imaginations of computers that can be carved into metal by automated milling equipment—but these are still "tweaks" to the original breakthrough.

Then there is the Internet. The first breakthrough in mammalian communication was speech—the ability to convey ideas more complicated than "want food!" or "escape tiger!" The next was writing, which allowed us to receive information from individuals long-dead

or too distant to meet face-to-face. The third was telecommunications, which allowed instant communication over unlimited distance. The fourth has been the Internet, which provides access, on demand, to all the information in the world, and which, since information is the fuel for technological breakthroughs, may be the most significant breakthrough of all. At Protomold, we've applied that technology to deliver sophisticated injection molded prototypes far faster and at substantially lower cost than is possible with traditional injection molding, and that's a breakthrough our customers really appreciate.

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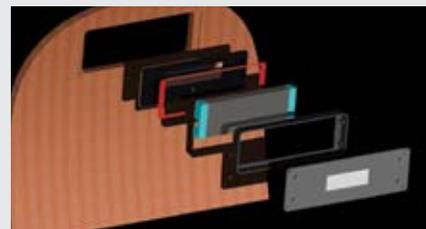
Opera Learns a New Language

Hear the word “breakthrough” and you probably think “medicine” or “telecommunications” or “materials science.” One of the last places you’d expect to hear the term is that grandest of performance arts, the opera. Yet, a breakthrough in the presentation of opera is exactly what Figaro Systems of Santa Fe, New Mexico has achieved with multi-lingual text display, wowing audiences around the world.

Opera blends spectacle, music, and language, but while devoted fans may study Italian to better understand Rossini or German for the sake of Wagner, many devotees have to settle

one of up-to-seven languages for simultaneous translation of the words being sung onstage. “We can deliver any of the galaxy’s written languages including Klingon,” says Geoff Webb, Figaro’s vice president of design engineering. Translations are provided by professional librettists and delivered during the performance by titlists, who ensure that each block of translated text is presented as it is sung onstage.

Figaro’s latest technology, the OLED, provides highly readable text that seems to float in the air with no distracting ambient glow. Audience members can turn off their individual



Protomold technology helps Figaro Systems develop customized prototypes for each installation.

“We can deliver any of the galaxy’s written languages—including Klingon,” says Geoff Webb

for just a general understanding of the librettos being sung. The introduction of “supertitles”—translations projected onto screens above some of the world’s great operatic stages—has delighted some and outraged others, but that technology leaves much to be desired. It is distracting to many, limited to one or two languages at a time, and poorly positioned for viewing from the best seats in the house. Figaro Systems solves all of those problems.

Figaro places small, three-line monitors in front of each seat. Viewers choose

monitors, but, according to Webb, about 95 percent of all attendees keep the monitors on during the performance. “It’s not at all distracting,” says Webb. “The positioning of the monitor is similar to that of a car’s instrument panel, allowing the viewer to take in information at a glance without losing track of what’s happening on stage. There’s even been research showing that captioning can improve understanding for those who speak the language.”

Figaro has installed systems (or

supplied proprietary software) at some of the world’s great opera houses including Teatro alla Scala in Milan, the Royal Opera House in London, Brooklyn Academy of Music, the Gran Teatre del Liceu in Barcelona, and the Wiener Staatsoper in Wien, Austria. One of the challenges of working in such notable venues is the need to satisfy architects, company directors, historic preservationists, and even city officials who must approve the installation.

The process can be challenging, but as Webb says, you can’t have opera without a little drama. “Fortunately,” he says, “working with Protomold lets us easily customize each installation. Protomold gives us quick turnaround for prototypes we can use for testing and approval, and once we have an approved design, they can give us the hundreds of parts we need for installation. Their aluminum tooling is quick and economical and perfect for our needs. Protomold provides a truly unique service, and they do it well.”

The Next Breakthrough in Rapid Prototyping

It wasn't long ago that prototyping was a strictly manual process. Designs were drafted by hand and then recreated in three dimensions by some labor-intensive process—an additive one like building up clay over an armature or a subtractive method such as carving a model from a block of wood or machining from metal. Many aspects of the process hadn't changed in centuries.

The first big breakthrough came less than a generation ago with the advent of CAD or computer aided design. This allowed users to design and modify components, not on paper but within a computer. This was accompanied by CAM or computer aided manufacturing (an ironic terminology considering that the word "manufacturing" stems from the Latin for "made by hand"). CAD was a widely available application, accessible, in its simplest form, as an off-the-shelf package for home users. Moving designs from CAD to CAM, however, was complex enough to be reserved for large-scale manufacturing and far too difficult for one-off or short-run prototyping, either additive or subtractive.

In the field of plastics, the next big breakthrough in prototyping was automated additive prototyping. This entailed direct connection of CAD models to equipment that produced three-dimensional prototypes by building up material to form a part. The most widely used processes were, and remain, stereolithography (SLA), fused deposition modeling (FDM), and selective laser sintering (SLS). The resulting prototypes were fast and affordable, but limited in resin choice and surface finish.

Protomold provided the next breakthrough in prototyping with rapid injection molding. Sophisticated proprietary software translates CAD designs into CAM instructions for subtractive CNC machining; the result is real injection molded parts with far less lead time and at far less cost than usual for injection molding. "While this does take somewhat longer than additive prototyping, it offers several advantages over additive processes: real injection molded parts in the customer's choice of resins and finishes.

The next breakthrough in plastic prototyping is just taking place. It is direct like additive rapid prototyping processes but subtractive like Protomold's process for making injection molds. Enabled by proprietary software and large-scale computing resources (100 Gigaflops and counting) it combines the advantages of additive prototyping—high speed and low cost—with those of Protomold's rapid injection molding process—choice of resins and finishes. This new, direct process will provide designers with fast, affordable, functional parts for design verification testing, which traditional additive rapid prototyping has never satisfactorily done.

First Cut Prototype, a new division of Protomold, is developing this process for CNC machined plastic parts. Started in October of 2006, with a focus on delivering very small quantities of machined plastic parts (Qty 1-10) very quickly (1-3 business days), the division has ambitious plans to expand its capabilities and capacity in 2007. If you have an application where an SLA, SLS, or FDM part just won't do, check out First Cut Prototype at www.firstcut.com or call 763-479-8600.

First Cut™ Prototype

The Ultem-ate Prototype

Do your prototypes need the heat resistance, solvent resistance, and flame resistance of General Electric's Ultem® 1000 resin? The bad news is that Ultem is one of the few resins in which Protomold cannot provide injection molded parts. The good news is that Protomold's FCP division can machine Ultem 1000 parts directly from your 3D CAD model. That means you can have high-quality Ultem 1000 parts suitable for functional testing shipped to you in as fast as one business day, and at a fraction of the cost of traditional injection molding.



First Cut Prototype provides designers with fast, affordable, functional parts for verification testing.

Designing with Acetal

Glenn Beall of Glenn Beall Plastics Ltd. (Libertyville, IL) shares his special perspective on issues important to design engineers and the molding industry.

1959 was an eventful year. Xerox introduced the first commercial copier. American Airlines launched commercial jet flights. Fidel Castro installed the first communist regime in the West. Alaska and Hawaii became states. The United States and Canada completed the St. Lawrence Seaway linking the Great Lakes to the Atlantic Ocean. And the DuPont Co. started producing Delrin.

In 1859 the Russian chemist Butlerov produced a brittle, white solid from formaldehyde. This was the precursor for polyoxymethylene or what we know as acetal. Nearly a century would pass before the industry produced the chemically pure formaldehyde required for highmolecular-weight polymers.

In 1952 DuPont put Robert Macdonald in charge of a project to develop new plastic materials based on formaldehyde. A major technical problem was the material's tendency to decompose to gaseous formaldehyde at molding temperatures. Thermal stability was improved

with the development of techniques for end-capping the molecules. DuPont made acetal homopolymer commercially available in 1959 under the trade name of Delrin.

In 1962 Celanese Corp. (now Ticona) introduced an acetal copolymer under the Celcon trademark. In 1990 DuPont added a copolymer to its offering.

The average cost of these two acetals in the early 1960s was \$.95/lb. Both materials were well received. Production reached 10 million lb in 1970 and the price dropped to \$.65/lb. Today sales exceed 400 million lb and the price for injection molding grades of acetal averages \$1.39/lb and \$.07/in³ in truckload quantities.

Defining characteristics

Acetals are opaque, semicrystalline thermoplastic engineering materials that are available as homopolymers or copolymers. The copolymers have slightly better melt flow and heat aging characteristics. All acetals are strong, tough, and stiff materials with a low coefficient of friction against metal and many other plastic materials. They are not hygroscopic and are resistant to a wide range of chemical reagents.

Acetal's chemical resistance allows it to be used as packaging and dispensing components for many solvents, fuel, and cosmetic products. It is, however, affected by strong acids or strong oxidizing agents. The Bic disposable cigarette lighter used acetal for its chemical resistance, dimensional stability, and pressure-containing stiffness. In fact, through the mid-1970s, Bic was the world's largest user of acetal.

Acetal is most frequently thought of for its impressive creep resistance. Its very low level of cold flow, coupled with excellent fatigue resistance, combine to make it the best available plastic material for springs. (The average values for general-purpose homopolymers and copolymers are shown in the table below.)

Many different acetals have been developed for special applications. PTFE filled acetals became available in 1964, followed by glass-fiber-reinforced grades in 1965. All of the properties in the table can be enhanced by adding fillers and reinforcing fibers. The one exception is impact strength. Acetals are notch-sensitive but tough materials that give a misleading low notched Izod impact value.

Special additives can produce toughened, less notch-sensitive grades. Acetals can be attacked by long-term exposure to ultraviolet light. Outdoor weatherability can be improved with additives. Other additives produce flame-retardant grades with a UL 94-HB rating.

Applications

Acetal's low friction, wear, and creep, coupled with its self-lubricating characteristics and long-term dimensional stability, make it the first choice for plastic gears, bearings, cams, and pulleys. These products find wide usage in many markets. Additional applications include:

Transportation: window cranks, door latches, shift levers, speaker grilles, mirror housings, and controls; fuel level sensors, pump housings, and gas

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Average values for GP Acetal

Property	Homopolymer	Copolymer
Tensile strength	10,000 psi	8800 psi
Flexural modulus	405,000 psi	375,000 psi
Notched Izod impact	1.8 ft-lb/in	1.25 ft-lb/in
Deflection temp. @ 264 psi	255°F	230°F

Copolymers have slightly better melt flow and heat aging characteristics.

caps; cooling fans, brackets, and trim strip clips; carburetor venturi tubes.

Electrical: coil forms and connectors; telephone terminal strips and fuse holders; switch and relay components; pushbuttons and key caps; videotape hubs and guides.

Plumbing: water faucet parts, stool flushing valves, filter bodies, and pressure regulator components; water meter housings and internal parts; pop-up lawn sprinkler and spray nozzles; water softener pumps, valves, and impellers; threaded fittings.

Consumer: dishwasher soap dispensers and spray nozzles; mixer bowls and blades; wear strips and instrument bodies in laundry washers and dryers; refrigerator shelf mounting brackets and door latches; mascara wands and vials; aerosol valves, nozzles, and sprayer pumps; springs.

Industrial: chain and conveyor links; gears and bearings; hose connectors; glue applicators, furniture casters, window and drapery hardware, cabinet hinges and latches; clock parts; small portable tool housings.

Part design tips

Wall thickness. Acetals are relatively easy-flowing materials. The recommended ideal wall thickness ranges from .030-.125 inch. Small parts have been molded with .015-inch-thick walls. With special molding procedures, large parts have been successfully molded with .750-inch-thick walls. The maximum allowable wall thickness for acetal should, however, be .375 inch. Thicker wall sections contain high levels of residual stress and are susceptible

to internal voids. Variations in thickness should be limited to 10-15% of the part's nominal wall thickness and be smoothly blended from thick to thin.

Corner radiuses. An inside corner radius equal to 75% of the part's wall thickness will minimize acetal's notch sensitivity. The minimum allowable inside radius is 25% of the part's wall thickness. This will also provide maximum strength, minimum molded-in stress, and improved melt flow.

Molding draft angle. Acetal is self-lubricating and some parts, such as bearings and gears, are molded straight without any draft angle. A 1/2-1° draft angle per side is recommended.

Projections. Many functional features such as stiffening ribs, solid bosses, and snapfit latches can be molded as projections off of a part's nominal wall. Their thickness at the junction with the part should be limited to 50% of the part's wall thickness. In cases where appearance and the absence of sink marks is critical, projections can be reduced to 40% of the part's wall thickness.

Depressions and holes. The main problems associated with depressions is that they create weldlines and the core pins that form small holes are difficult to cool and are susceptible to bending. Weldlines can weaken a part while creating appearance problems. The weldline on a properly molded part can

retain 80-90% or more of the material's original tensile strength.

Acetal's ease of flow allows the use of low injection pressures. These lower pressures reduce the bending forces on the core pins that form small holes. All inside corners on holes should have the standard radiuses. As the material shrinks, it grips the core pins. Providing molding draft on these core pins reduces ejection force, which allows shorter molding cycles.

Tolerances. Acetals are dimensionally stable materials in spite of the fact that they have a high mold shrinkage factor. Acetals are widely specified for precision parts, such as bearings and gears, that have to retain their size for extended periods of time. The attainable tolerance is determined by the material's shrinkage factor, the part's thickness, and the molding conditions.

A commercial tolerance on a 1-inch long, .125-inch-thick molded acetal part is ± 0.0056 inch. A more costly fine tolerance on that part is ± 0.0030 inch.



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What's New

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Protomold US is now exporting to customers in 11 countries including Australia, New Zealand, Japan, Mexico, South Korea, Canada, Israel, Chile, Singapore, and India.

Meanwhile, Across the Pond ...

Our plant in Telford, UK is working overtime to meet demand in the EU. Protomold UK can be reached via www.protomold.co.uk.

And on the Other Side of the World

The incorporation of Protomold Japan is now complete. Exactly when and where operations will commence is being determined. We will make announcements shortly, but if you have, or know of operations in Japan that could use Protomold's services, watch for an e-mail update.

Oh, All Right, We'll Shout it from the Rooftops ...

For those of you who may not have noticed (and we've been surprised at how many of you there are), Protomold can now handle up to four side actions in a single mold. Sure, we've spent years showing you how to avoid undercuts and overhangs—and you can still save money by doing so—but sometimes they're unavoidable, and sometimes we can help.

Oh, and by the way, we can now mold parts up to six inches deep. For details, go to www.protomold.com/designguidelines/size/.

First Cut Prototype—Directly Machining Plastic Prototypes FAST!

Want machined prototypes? Our new division, First Cut Prototype™, launched in October of 2006, applies our proprietary technology to direct machining of plastic prototypes from your 3D CAD model. This unique approach gives you the speed and economy of traditional rapid prototyping but with real engineering plastics. So when you need a few parts suitable for rigorous functional testing, quickly and affordably, see FCP at www.firstcut.com.

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Engineering Manager Chuck introduces his latest breakthrough, **The Bass Boat on Wheels**, at the department's winter fishing retreat.

A Peek Inside the Mold

Ever wonder what happens when liquid resin is injected into a mold? ProtoQuote® now includes, with selected quotes, our proprietary ProtoFlow® simulation of resin flow. It's not exactly PlayStation3, but it can help show why some of the principles of injection molding design are important.

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