protomold®

Rapid Injection Molding JOURNAL™

Winter 2005

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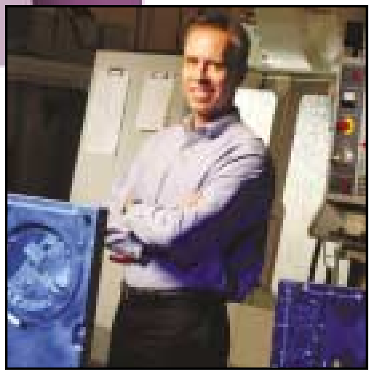
EXECUTIVE VIEW



Synergy

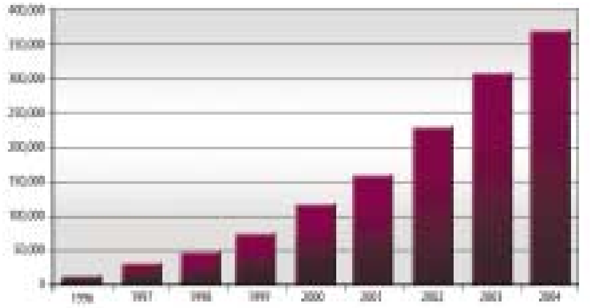
synergy (sin'ər jē), n.
interaction or cooperation of two or more agents to produce a combined effect greater than the sum of their separate effects.

This has been an extraordinary year for Protomold. The company placed 48th in Deloitte's 2004 Technology Fast 500 (Google™ was #1). The Business Journal (Minneapolis-St. Paul) named us number one among their Growth 50 Private Companies, and we won the 2004 Minnesota Tekne Award for Advanced Manufacturing Company. We'd like to think that hard work and good decisions have played a role in our success, but external factors have contributed as well.

The first of these is globalization. Growing markets and expanded competition have put product development on permanent fast forward. Yesterday's processes can't always get today's products to market while there is still a profit to be made. Nor do they allow the iterative testing and tuning that makes a product competitive. Fortunately for us, Rapid Injection Molding does both.

Exponential growth in number of 3D CAD seats.

Data courtesy of SolidWorks, Inc.



The second factor is affordable 3D CAD software (see chart). Once available to only the biggest spenders, these powerful applications now speed up and simplify the design of sophisticated parts for mere hundreds of dollars. For Protomold customers, 3D CAD models enable our automated ProtoQuote® and mold-making software, eliminating unnecessary cost and delay.

Finally, there is the Internet. As in so many fields, it has allowed our customers instant access to Protomold. By eliminating the communications overhead that we all took for granted a mere decade ago, it has made our Minnesota company everyone's "neighborhood" source for prototype and short-run production parts. So, while we'll take partial credit for our success, we also credit the fortunate circumstances around us. And, of course, the customers who know a good thing when they see it.

Brad Cleveland
President & CEO
bradc@protomold.com

At Protomold, we *don't* do it all

Ask a custom manufacturer of plastic parts what they can do for you and the answer will probably be "anything you want." That has a certain appeal, a sense of freedom and possibility. But while the implication is that you can have it all – and an experienced mold maker can probably produce just about anything you want – there are two things that even the best mold maker in the world can't give you…speed and economy.

At Protomold, our software and manufacturing processes place definite limits on what we can produce. What we can always provide, however, are speed and economy along with the material choices you'd expect from traditional injection molding.

At the same time, we continue to push back our limits. For example, we can now make larger, deeper molds than we could just a few months ago. We can make more complicated parts, are no longer limited to simple straight-pull molding, and can offer up to two side actions per mold. In other words, within an ever-increasing range of requirements, Protomold customers actually can have it all.

Our challenges are:

1. To continue to expand the capabilities of Rapid Injection Molding.

2. To help designers identify parts that can take advantage of the most current Rapid Injection Molding capabilities.

3. To help customers adapt non-conforming designs to take advantage of Rapid Injection Molding without compromising functionality.

The primary tool for matching customer needs with Protomold capabilities continues to be our ProtoQuote® interactive quoting and design evaluation software. At the same time, we offer design tips and other features of this publication as resources for the parts designer. As a result, for an increasing number of designers and an increasing number of designs, you truly can have what you need, when you need it, and at a price you can afford.

ACROSS THE GREAT DIVIDE

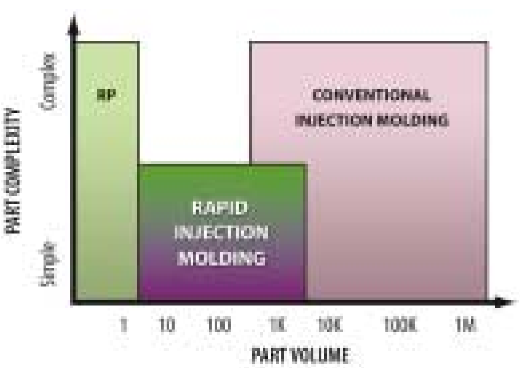
Goldilocks had it right. In a world of "too hot" and "too cold," you need a middle choice. Once upon a time, plastic part designers faced the same dilemma. Rapid prototyping could provide a few parts quickly and at relatively low total cost, but those parts typically fell short of production quality. Conventional injection molding on the other hand, delivered true production quality, but mold making could take weeks and cost tens of thousands of dollars.

Each of the two methods has its place in the product development process, but changes in the market have created a widening gap between them. Competitive pressures have fueled a never-ending race to be first to market. Product life is shrinking. And customer expectations — for style, for quality, and for functionality — are on the rise.

Rapid prototyping – stereolithography, fused deposition modeling and the like — has changed, and continues to change, the way designers work. "3D printing," whether on the desktop or through a service bureau, produces prototypes that can be evaluated for shape and size in ways no drawing can. It allows designs to be tweaked, evaluated, and tweaked again in hours or days instead of weeks or months. But even with the best of today's rapid prototyping technology, these are not production parts. They come in a limited range of materials and neither look nor perform exactly like the final products they represent.

Of course, prototypes can certainly be produced by conventional injection molding, and if the parts pass muster they can immediately be used in production. However, if for some reason the prototypes don't meet the design requirements, all the time and money associated with conventional tooling will be lost. Therein lies the gap!

Rapid Injection Molding bridges that gap. It cannot produce an approximate prototype as quickly or inexpensively as rapid prototyping, but it delivers true production-quality parts in the same material that will be used in manufacturing. Rapid Injection Molding is not as economical in long-run production as conventional injection molding, nor can it produce parts with the highest level of design complexity. But it is fast and economical enough to meet both prototyping and short-run requirements. It can even be used for bridge tooling in interim production while final production tools are being manufactured.



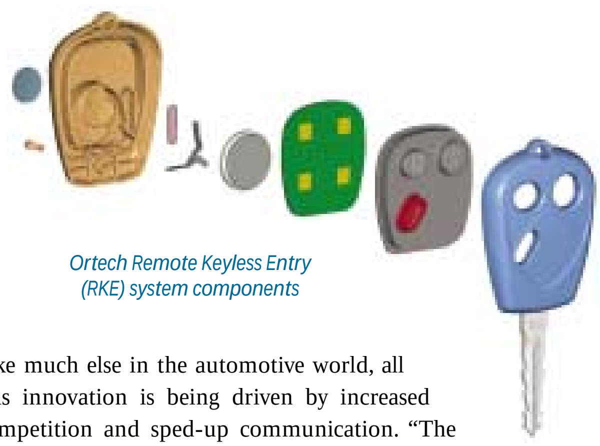
Consider for example the development of a new medical device. Initial prototypes may be produced by stereolithography for evaluation of form and fit. The design may then be reproduced by Rapid Injection Molding for functional or laboratory testing and/or FDA evaluation. The Rapid Injection Molding parts could actually be used for production, providing a "bridge" while conventional steel molds are manufactured. Finally, large scale production could use conventional injection molding.

As far as we know, little Goldilocks never studied engineering or design, and her field of expertise was porridge, rather than plastic. But she proved herself an authority on the concept of the happy medium. We'd like to think that her expert evaluation of Rapid Injection Molding would be, "This one is just right!"

Driving Innovation at Ortech

"It's imperative that our prototyping process accommodate our rigorous design validation testing methods,... Product validation starts with design validation. "

Pity the poor car thief. It wasn't that long ago that opening a car door and starting the motor were purely mechanical processes. Keys could be duplicated or locks picked. With a bit of training and practice, it really wasn't all that hard. Today's increasing emphasis on security is changing all that. Mechanical car locks and ignitions are increasingly part of integrated electronic systems. But the changes affect more than just the locks; they run through the entire vehicle and are even impacting the once-humble car key.



Ortech Remote Keyless Entry (RKE) system components

Like much else in the automotive world, all this innovation is being driven by increased competition and sped-up communication. "The Big Three" were once auto manufacturing companies. Today, that term could be better applied to the car-making continents of Asia, Europe, and North America. Buyers face more choices than ever before. They shop the Internet, and if they see a dealer at all, they arrive armed with detailed product and pricing information. And, while the average family may own more cars than in previous decades, those cars do more and last longer than ever before. In short, expectations have ballooned.

To keep up with demanding consumers and stay ahead of competitors from around the world, car companies and their suppliers have to be innovative, cost-effective, and faster than ever before. Ortech, a Kirksville, MO manufacturer of automotive components, faces all of these pressures in the manufacture of remote keyless entry (RKE) systems (see illustration).

RKE is based on transponder chips, which send and receive the radio frequency signals used to unlock car doors, open trunks, and set alarms. Until recently, the state-of-the-art miniaturization of these chips allowed them to be placed in key fobs. But as components continued to shrink, the next logical step was the relocation of these already-miniaturized components into the key itself. In addition to the obvious difficulties of miniaturization, the finished product had to withstand rough handling, be attractive and easy to use, and meet stringent deadlines. This presented Ortech designers with several new and significant challenges.

"Because of the large number of components with which the key lockset must interact, six or eight re-designs may be required," says Ortech Design Manager Brian Bolton. These changes, according to Bolton, are typically driven by the customer. "We are expected to meet each design deadline with controlled costs and constant quality."

Most of these are not paper-and-pencil designs, but fully functional prototypes. "It is very critical to end-product success that we can make sure the transponder is going to function properly with the presence of RKE electronics, and vice versa," Bolton says. To add to the challenge, each subsequent redesign typically allows less turnaround time than the one before. This, of course, is hardly unique to Ortech. It's all part of the auto industry's new "go-fast" approach. Design programs that would have taken 36 months just 15 years ago may now only get 18.

"The positive results we experienced using Rapid Injection Molding for our key locksets made us reevaluate our established prototyping process,... Previously, we were limited in terms of quality and speed, but with Rapid Injection Molding, we're able to accomplish our design goals in ways we never thought possible. "

RKE prototype components

Prototype parts from Protomold

"It's imperative that our prototyping process accommodate our rigorous design validation testing methods," Bolton says. Product validation starts with design validation. Prototypes are subjected to tests such as mechanical endurance, environmental exposure and thermal shock to verify that the product is ready for real-world operation. To ensure the validity of these tests, each prototype must be free of disparities like warping, shrinking, or poor surface condition. Such departures from the specified design could potentially force the unnecessary redesign of other parts, or worse yet allow the passage of prototypes that will not function in actual production models.

While it addresses functionality, Ortech's multi-step prototyping process must also address the aesthetics of the final product. In the case of keys and locksets, these are particularly important, as these are external components that are both seen and touched by users. "We have to eliminate any exterior blemishes, like grain smudges, sink marks, flow lines, or visible parting lines," says Bolton.

Ortech had been using a variety of prototyping methods, including stereolithography, pour-molding polyurethane in rubber molds and in-house tooling. While these had been satisfactory in the past, the requirements of the new project had significantly raised the bar. "We knew from experience that our previous prototyping methods wouldn't work for the RKE design demands," says Bolton. "We had been hearing about Rapid Injection Molding, so we decided to put it to the test." After submitting a 3D CAD design, Ortech designers got back an interactive ProtoQuote®, including suggested design changes, within a day. Prototypes were finished in just two weeks (see photo). The company saved approximately $20,000 over traditional molding methods and was able to begin design validation sooner than expected.

"The positive results we experienced using Rapid Injection Molding for our key locksets made us reevaluate our established prototyping process," Bolton says. "Previously, we were limited in terms of quality and speed, but with Rapid Injection Molding, we're able to accomplish our design goals in ways we never thought possible. The fact that the parts look great and are very representative of mass production appearance is a bonus. I believe that the good appearance of these parts…helps us stand out from competing suppliers." Based on the success of the RKE development, Ortech has already incorporated Rapid Injection Molding into other current work and plans to make it a part of their ongoing prototyping activities.

Completed functional RKE prototype

The Faster, the Better

What could a five year-old manufacturing company and a twelve year-old sports car have in common? If the company is Protomold and the car is CEO Brad Cleveland's Mitsubishi 3000 VR-4, the answer is "quite a lot." For starters, each has been the focus of Brad's attention over the last several years and undergone significant change. Each began with a unique approach in its market, and each has the same primary focus: speed.

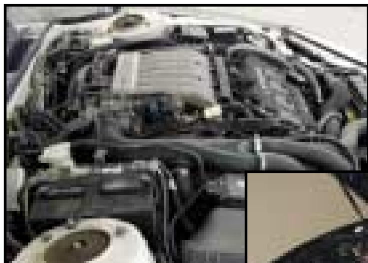
The VR-4 was Brad's daily transportation for 10 years after he purchased it in 1992. Its four-wheel drive was unusual for a sporty vehicle, and its four-wheel steering, rarer still. Fitted with Z-rated snow tires, it was capable of over 100 mph in the snow, though Brad claims never to have tested that capability in a Minnesota winter. But even with the best of care, after 10 years and 120,000 miles the car was showing its age.

"The VR-4 originally appealed to me because it was so radically different from anything else on the road," says Brad, "just as Protomold is different from other custom manufacturing companies. The main objective of the car project was just to have some fun seeing how powerful it could get."

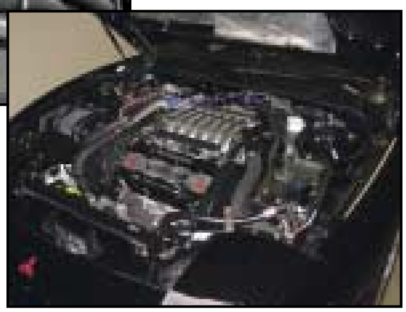
As with Protomold, building up the car was a team effort. "I've been fortunate throughout my career to work with people who are better at their jobs than I could ever hope to be," Brad insists. "At Protomold, cofounders Larry Lukis and Gregg Bloom are experts in software development and mechanical engineering, respectively. Our VP of operations, Mark Kubicek is an authority on business functions and customer interface. All three are exceptional at what they do, as are all of the people we work with at Protomold." In the same way, according to Brad, mechanic Jack Hietala and body man Joe Ebenhoh, each of whom oversaw much of the VR-4 upgrade, are recognized leaders in their respective fields.

Ever the CEO, Brad is quick to point out that he stayed involved with every aspect of the car project. "I took Jack, the mechanic, out to lunch half-a-dozen times during the planning phase," he says. "We looked at a dozen different approaches before deciding exactly what we were going to do. It's the same method we use for problem solving in business. We try to involve representatives of all related areas, develop a consensus definition of the problem, and then look at a variety of possible solutions.

Actual work on the car began in January 2003 with blueprinting of the six-cylinder 24-valve, dual overhead cam engine. Modified intake, y-pipes, and larger twin turbos were added to maximize air flow. The exhaust system was "opened up" to eliminate any power-robbing back pressure. Oversized fuel injectors and a larger fuel pump increased fuel delivery to the cylinders, and a modified boost controller reshaped the engine's power curve. The clutch, Brad points out, is still stock.



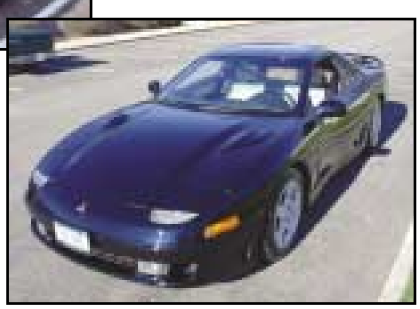
Before modifications



After modifications

The effects of these changes include an almost 50 percent increase in horsepower (from 300 to 440), a reduction in 0-60 time from 6.3 to under 5.0 seconds, and an increase in theoretical top speed from 170 to 185 mph. While the car was being modified, Protomold too was undergoing some redesign. The company invested heavily in technology and development; nearly tripled office, warehouse, and manufacturing space; and increased headcount from 30 to 95. Like the car, the company got a substantial boost in output: revenue increased from just under $3 million in 2002 to almost $11 million in 2004.

Before restoration



After restoration

Having completed the car's performance modifications, Brad turned to cosmetic issues. The body of the vehicle was completely disassembled and parts were restored or replaced as necessary, painted, and reassembled. The decision to address performance first and then appearance was no accident. "We're doing the same thing at Protomold," says Brad. "We believe you should have the goods before you start blowing your horn. Now that we've expanded and upgraded the company's capabilities, we're taking steps to let the market and industry know. Our quarterly Journal is part of that process, and we're also revamping our web site, print ads, and direct mail programs."

The Goodies

Modifications to the 3000 VR-4 include:

- K&N open air intake
- HKS electronic valve controller boost control & gauge
- Twin GTPro GT-357 magnum turbos
- Greddy type-S blow-off valve
- DN Performance Y-pipe
- RC Engineering 550cc fuel injectors
- Denso 195130-1020 fuel pump
- APEXI Super Air Fuel Controller II
- DN Performance pre-cat eliminators
- 3SX Custom VR-4 downpipe
- UltraTech hi-flow catalytic converter
- Borla cat-back exhaust

So, where will it all end? "I bet I'll never leave that car alone," says Brad. "It's too much fun looking for ways to make it a little more interesting to drive." Plans for the Mitsubishi's immediate future include a thorough interior renovation and upgraded audio. Protomold, too, will be subject to ongoing improvement. "We want to be able to do more for our customers, to be able to produce larger, more complicated parts," Brad says. "But we're not going to lose track of what keeps them coming back. We'll always be the fastest."

Contemplating Gating

When you order parts from Protomold, our automated system designs the mold in which your parts will be made. Somewhere in the mold design is the gate through which plastic material will enter the mold cavity. Since the gate ends precisely where your part begins, the question is, should you care about gate design? And the answer is, yes…possibly.

Gate design can have a broad impact on how your parts look, what they cost and Protomold's ability to quickly deliver good parts. These are all issues that Protomold considers in choosing an appropriate gate design for your part.

Of the various gate types available for injection molding, Protomold uses four: edge gates, tunnel gates, post gates, and hot tip gates. Each has its own advantages and drawbacks.

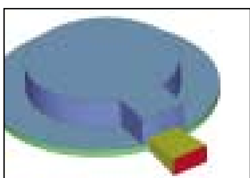



Figure 1.
Edge Gate

An edge gate (Figure 1) is cut into a face of the part. It results in extraneous plastic leaving the mold attached to the edge of the part at that location. It is simple to create and use and can be large enough to fill very thick parts. However, it must be trimmed off after molding and may leave a gate vestage where it is removed. Depending on the surface chosen for the gate, the vestage may be a cosmetic issue.

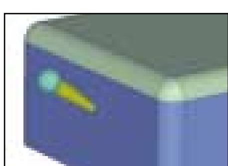



Figure 2.
Tunnel Gate

A tunnel gate (Figure 2) is drilled below the surface of a mold. Removal of the part from the mold automatically clips off the gate, saving significant labor in high-volume production. As with an edge gate, removal of a tunnel gate can leave a gate vestage, but because it is smaller this may be less of a cosmetic issue. This is not a preferred method for use with glass or mineral filled resins due to the additional wear and tear on the aluminum mold.

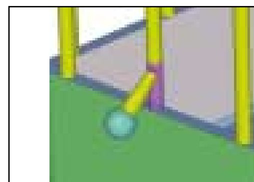



Figure 3.
Post Gate

A post gate (Figure 3) feeds plastic into the mold through an ejector pin hole. The ejector pin ends just short of the gate, and shears off the gate as the part is ejected, leaving a short post to be removed from the part. Since this post is on the ejector side of the part, it is less frequently a cosmetic issue.

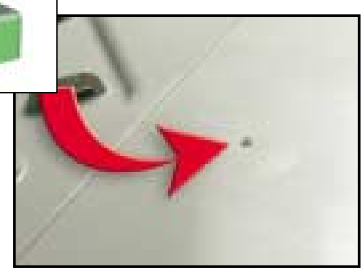



Figure 4.
Hot Tip Gate

A hot tip gate (Figure 4) is a heated nozzle that feeds material directly into the mold cavity. The gate vestage is a small bump on the finished part, which can be either recessed or trimmed off after molding. Hot tip gates are on the side of the part opposite the ejectors, which is often the cosmetic side. Sometimes it can be hidden behind a label when the part is used in assembly. This method can leave a gate blush, a discoloration around the gate area.

When you order a mold from Protomold, the order confirmation will incorporate one of these gate designs, which you can approve or request us to change. If you have any questions about a proposed design, please feel free to contact our customer service at (763) 479-3680.

In this issue of the Rapid Injection Molding Journal we have incorporated an excellent article originally published in the October 2004 issue of Injection Molding Magazine. We hope you find it interesting and useful.

Designing with PPO

YOU CAN PLATE IT, LEAVE IT IN WATER, AND USE IT IN ELECTRICAL APPLICATIONS WITH NO BURNING. IF YOU NEED SOMETHING BETTER THAN ABS, GO WITH PPO.

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

The initials PPO are the easy way of saying polyphenylene oxide.This is a misnomer for polyphenylene ether, or PPE, which is the European designation. The original PPEs found limited applications due to their relatively high cost. The material was also susceptible to thermal degradation at processing temperatures.

In response to these limitations, General Electric's (GE's) John Hay discovered that PPE was completely miscible with polystyrene (PS). Alloying PS with PPE produced a lower-cost material with a broader processing window. In 1966, GE Plastics reintroduced this new material as a PPO under the now well-known trade name of Noryl. This polymer found many applications, but it was a single-source material. Some large potential users, such as the car and computer companies, were apprehensive about specifying a material that was only available from one supplier. This marketplace opportunity was recognized by Borg Warner (BW), a highly respected supplier of Cycolac ABS materials. In 1982, BW introduced Prevex, a PS-modified PPE with similar properties. This material found a waiting market. Both Prevex and Noryl continued to expand their market share. Sales were 29 million lb in 1970 and expanded to an impressive 227 million lb in 1998. Sales in 2003 are estimated at 300 million lb. GE purchased BW's plastics business in 1988.

DEFINING CHARACTERISTICS

The styrene-modified PPOs are amorphous, opaque, engineering materials known for their stiffness and impact strength coupled with good temperature resistance. Varying the percentages of PPE and PS allows this material to be adapted to many different molding processes and market applications. Filled and fiber-reinforced grades are available, some with Underwriters Laboratories' 94 flame retardancy rating of V0 and 5V. General purpose, injection molding grades are priced at \$1.80/lb or \$.068/cu in in truckload quantities.

There are too many grades of PPO to be summarized here. One popular flame-retardant injection molding grade of Noryl (N 190) has a tensile strength of 7000 psi and a flexural modulus of 3.25 x 105 psi, with a notched Izod of 7 ft-lb/in and a heat deflection temperature of 205°F at 66 psi. Mineral-filled and glass-fiber-reinforced grades have much greater tensile and flexural strength with higher temperature resistance. Modified PPO is a bridge material that successfully fills the gap between polycarbonate and ABS.

TYPICAL APPLICATIONS

This versatile material finds uses as communication, medical, appliance, and business equipment and housings. Transportation applications include wheel covers, instrument panels, grilles, and electrical components. This material's low hydrophilic characteristics allow its use in long-term contact with water for pumps, sprinklers, fittings, tanks, pipe, and water meters. Electroplated parts are used for EMI/RFI shielding, appearance type plumbing applications, and as automotive and appliance trim. PPO's excellent electrical properties and nonburning characteristics combine to allow its use as junction boxes and covers, coil bobbins, wiring terminal boards, fuse blocks, fire alarms, exit sign housings, and current-carrying switch gears.

In those instances when ABS or impact styrene is just not quite good enough, PPO is the next best choice.

SPECIFICS OF PPO DESIGN

Wall thicknesses *of .060 to .180 inch are ideal for PPO. Thicknesses of .030 to .375 and even .500 inch have been molded. Flow lengths of 10 inches can be molded with a .060-inch wall. Walls .125 inch thick can be up to 25 inches long. A tolerable wall thickness variation can be 25% with proper blending from thick to thin.*

Radiuses *improve melt flow and reduce stress. A good inside corner radius for PPO is one-half of the part's wall thickness and never less than .015 inch.*

Molding draft angles *of 1/2° to 2° per side are recommended for PPO. Textured surfaces require a draft angle of 11/2° plus 1°/side for each .001 inch of texture depth.*

Projections *such as ribs, bosses, and gussets on parts with walls less than .125 inch can be 50% to 60% of that wall thickness. These values should be reduced to 40% to 50% on parts with thicker walls.*

Depressions, *or holes, create weldlines. With proper molding procedures, these weldlines will not cause appearance or abnormal strength problems. Weldlines are rarely as strong as the surrounding material. They should be located in low-stress areas. Holes require standard molding draft and corner radius considerations. Limiting the depth of holes to two to three times the thickness of the core pin eliminates pin deflection.*

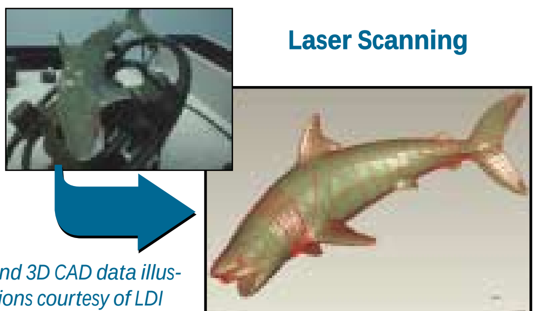
Tolerances *on PPO parts can be as fine as ±.001 inch on a .125-inch-thick, 1.000-inch-long part. A less costly commercial tolerance on the same part would be ±.002 inch. There are always exceptions and not all parts can maintain these tolerances all of the time. This is a low-mold-shrinkage material that shrinks uniformly in all directions. PPO is frequently chosen for large, precision parts that require a minimum of warpage.*

Shifting Into Reverse

Rapid Injection Molding always begins with a 3D CAD model from which Protomold's mold-design software gets its instructions. When creating a part from scratch, a designer has his or her choice of field-tested software packages that can turn a concept into detailed, three-dimensional digital output.

But what if the original is more than a concept? What if the model already exists? The answer is reverse engineering, essentially the same process that occurs when you leave a six year-old boy alone with a cuckoo clock: taking something apart to see how it is put together. In the case of a plastic part, it consists of analyzing geometry to create a "point cloud" data file. That file can then be converted to a standard CAD format like IGES or STEP, which can be read by Protomold's software.

Laser Scanning



Part and 3D CAD data illustrations courtesy of LDI (Laser Design, Incorporated).

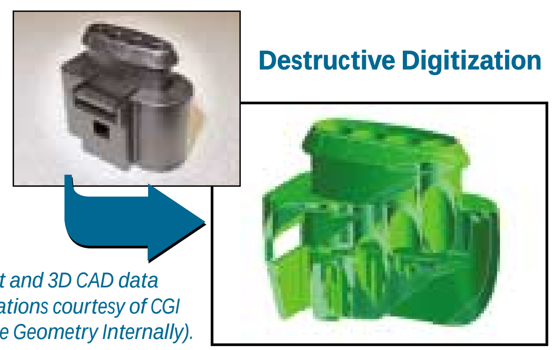
There are two primary approaches to creating the point cloud data file, both available either as equipment for purchase or as a service.

When all surfaces of the part can be directly viewed from the outside, laser scanning is used to collect information for the data file. The process is essentially one of triangulation. Light from a laser source is bounced off each point on the surface of the object being scanned and collected by a video camera. Since the geometry of the light source and camera are known, the location of the reflected light in the image plane of the camera can be used to locate a point in space using trigonometry.

When there are surfaces that cannot be directly viewed, either because they are located on the interior of the part or because they are hidden behind other external features, a data file can be created by a process of "destructive digitization." Here, the part is literally sliced into ultra-thin layers and the individual slices scanned with a digital camera. Data from scanned slices is reassembled by software into a point cloud data file showing "every draft, angle, radius, plane, curve, and void" of the original part.

In either case, the resulting digital representations of the original parts can be used to create the 3D CAD model needed for the automated quoting, design and manufacture of the molds characteristic of the Rapid Injection Molding process.

Destructive Digitization



Part and 3D CAD data illustrations courtesy of CGI (Capture Geometry Internally).

BOOK REVIEW:

JOINING OF PLASTICS:

HANDBOOK FOR DESIGNERS AND ENGINEERS

By Kevin Crystal, Protomold Senior Quality Engineer

Joining of Plastics: Handbook for Designers and Engineers
2nd Rev edition (April 1, 2004)
Author: Jordan Rotheiser
Publisher: Hanser Gardner Publications
ISBN: 1569903549

serendipity (ser ən dip′ ə tē), n. the faculty of making desirable but unsought-for discoveries by accident.

We were actually looking for a book on resin selection for engineers and designers when we ran across this one. It does, in fact, have an excellent section on resins, 34 of them to be exact. But its exhaustive coverage of other aspects of plastic design, including 22 processing methods and 15 methods for joining plastics, make it an excellent all-around choice for both casual and full-time professionals working with plastics.

The preface points out that it is "more complicated to design with plastics than with metals," yet the book is designed to allow easy access to a rich store of valuable information. For instance, in Section 5.4.1 the author lists key properties for each generic resin group. Acetal, for example, boasts very high tensile strength, toughness, stiffness and dimensional stability, high abrasion resistance, and resistance to chemicals and creep under load. Section 5.4.3 provides SPI tables for each resin, including both fixed and variable tolerances. Tolerances listed as "commercial" in the tables are approximately what can achieved via Rapid Injection Molding. This chapter also addresses applications, assembly methods, and weldability for each of the plastics.

The discussion of joining plastics begins with the very first chapter. Here you'll find an overview of assembly methods, specifically addressing strengths and limitations, typical applications, and processing methods. From here, the reader is directed to other sections of the book where specific issues are addressed in more detail.

As suggested by the title, it is methods of joining that get the author's closest attention. Chapters two through four address design for efficient assembly, cost reduction in assembly, and design for disassembly and recycling. Chapters five and six cover matching assembly method to material and production process, respectively. Chapters seven and eight cover adhesive and solvent joining (including issues such as surface energy treatments to make olefins glueable) and fasteners and inserts (both molded-in and post-processed). Chapter nine focuses on hinges.

Seven chapters of the book are devoted to welding methods including fusion and resistance welding, hot gas welding, induction welding, spin welding, ultrasonic welding, vibration welding, and laser welding. Other chapters address a variety of fits – force, shrink, snap, and more including issues of stress prevention – tapped and molded threads, and miscellaneous forming methods.

All in all, this is an encyclopedic work that takes an enormous amount of information and makes is readily accessible for either study or reference. It is well illustrated and well supplied with charts and tables that simplify complex data. And, finally, for those who plan to actually make parts, it provides detailed information on material suppliers and equipment manufacturers.

WHAT'S NEW

Protomold News

Recognition – Protomold was recently named as the fastest growing private company in Minnesota and the 48th fastest growing technology company in the USA or Canada (Google™ was #1).

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