Feature

Molding The Future Advancements In Injection Mold Design and Processes

by Jeffrey Rowe

As practiced today, the principles of basic injection molding have changed surprisingly little since the original injection molding machine was created in 1872 by two brothers, I.S. and J.W. Hyatt. Their patented machine injected molten cellulose nitrate into a closed mold held in a vertical hydraulic press. This process was hardly practical, however, because of the dangerous thermal instability of cellulose nitrate. It wasn't until the 1920s when an improved molding machine and a safer material, cellulose acetate, were jointly developed did injection molding become practical. These joint developments are what are credited for introducing the industrial world to the so-called "Plastics Age."

Today, as in the past, the injection molding process involves heating thermoplastic granules or pellets until they are liquid, and then injecting the hot liquid under pressure into a relatively cold mold where the material "freezes" and takes the shape of the mold cavity. Heat is the only mechanism in basic injection molding when using thermoplastic resins. There is no chemical reaction that causes the thermoplastic resin material to solidify (those materials are known as thermosets).

Although there are several types of injection molding, regardless of type or process, the major advantages of injection molding include:

- Usable, finished, flash-free parts right out of the mold
- Many parts can be produced simultaneously
- Tooling can have exceptionally long life, especially if non-aggressive plastic resins are used
- Scrap from flash, sprues, and runners can be reground, mixed, and reused with virgin material.

The three main variables in injection molding are:

1. Machine type
2. Process variables - temperature, pressure, and time
3. Thermoplastic resin type

Efficient plastic part production is often a delicate balance between choosing the right machine and resin type and adjusting the three process variables. There are also a number of other factors that weigh in for producing parts competitively, such as the overall level of automation and ancillary equipment and processes.

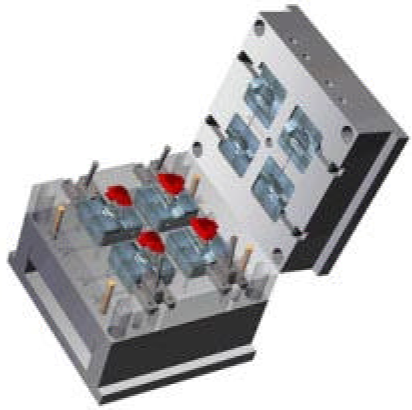

image courtesy of R&B Mold and Die

The Mold Is The Thing

The mold is what determines the shape, and in most cases, the final finish on parts. Most injection molds are comprised of two halves - a cavity (also called the female half of a mold) and core (also called the male half). While the core and cavity are usually highly machined, molds also consist of many other parts that require little or no machining or shaping, such as pins, plates, bushings, etc. Most molds are produced through either traditional machining or electro discharge machining (EDM), although rapid prototyping and tooling techniques are gaining a foothold. Traditional machining simply removes material with a cutting tool for producing cores and cavities, whereas EDM is used to produce cores and cavities that would otherwise be difficult or impossible to machine using traditional methods.

Until relatively recently, software's role in the product design process was well known, but its role for mold design was somewhat obscure. Today, however, there are a myriad products for not only designing tooling for injection molding, but also for optimizing cycle times and throughput. This is an especially noteworthy development, because injection molds can be among the most complex tools used in manufacturing, far beyond just the core and cavity, with heating and cooling systems, part ejectors, resin injectors, etc. Mold design software available today is a study in contrasts - it is getting more affordable and easier to use, but is also getting more sophisticated capabilities. Mold design today is being influenced by design software, as well as other processes, techniques, and issues.

Although costs have been reduced quite dramatically in most other areas of the product development process, the most time consuming and costly phase for plastic parts remains tooling, especially if prototype tooling is part of the program. One way around this bottleneck is to hand off some part designs so toolmakers can get started while designs for other parts are completed. While this procedure can save time, can be risky. Another potential time saver is to forego prototype tooling and spend more time and effort on designing more accurate production tooling.

Not too surprisingly, some of the issues that moldmakers find most challenging and pressing include:

- CAD data file translation and surrounding issues
- Keeping abreast of new, emerging technologies
- When to employ simulation and analysis techniques
- Increasing communication between moldmakers, suppliers, and customers
- Adding value that customers can appreciate and understand
- Implementing collaborative design techniques
- Reducing overall costs for design process, tooling, and final product
- Reducing time to market through accelerating product and tool development

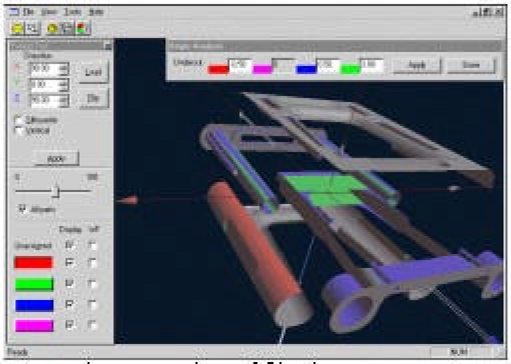

image courtesy of Cimatron

The Digital Influence

In many circles, computer technology is regarded as the biggest innovation in the injection molding process since the advent of collapsible cores, but there still is a sizeable resistance to universal acceptance. Many mold shops are not yet connected to the Web, much less have they put forth much effort to networking their facilities for gathering data for analysis. One of the reasons for this relative lack of presence is because of the inability to share information between machines produced by different vendors, since many offer only proprietary, closed architectures.

On the other hand, open architecture controllers running integrated production equipment with monitors networked into production planning, accounting, and procurement systems could save vast amounts of time and money. Computers, connectivity, and Web access are becoming increasingly indispensable tools for collaboration and communication between suppliers, molders, and customers, as well as the ability to handle mass customization while providing lower costs. However, today probably less than one percent of molders are at this advanced state. Overall, it does not appear that collaboration, online design, and analysis tools accessible over the Web have quite caught on yet with the molding community. Molders must overcome resistance to change and increase their spending on information technologies from an average of two percent of gross revenues to four to six percent. Doing this will help them take advantage of B2B e-commerce sales that are expected to reach $1.6 trillion by 2003.

The Effects of RP and RT

A branch of rapid prototyping (RP) is making its presence felt in moldmaking in the form of rapid tooling (RT). Although there are different approaches, we'll concentrate here on alternative direct tooling where an RP machine actually builds mold core and cavity inserts, and doesn't require a pattern. Beyond what the name implies, RT is often not only a faster way to produce tooling, but can be significantly less expensive, as well. Also, RT can provide aspects and features to molds that are not possible with conventional machined tooling. For example, with RT, cooling channels that trace around a round part, reducing hot spots that might prevail with straight or square cooling channels.

RT is often looked upon as temporary tooling, as opposed to permanent, but can be well-suited for prototyping, short production runs, or productions runs of parts that require only low injection pressure to produce parts.

As prominent as RT is becoming, it is not without its own inherent risks and limitations. For the most part, plastic molds produced by RT methods usually are not as durable as those produced with conventional machining methods, so more care must be practiced during their production lives. In other words, don't expect to get as many shots with an RT mold as you would with a machined mold. Because a number of production variables may be different when using RT molds, some mechanical and physical properties may be compromised and different than those resulting from production tools. Finally, as far as RT has come, it's not quite to the same level of machined tooling when it comes to tolerances and detail refinement. Even with these limitations, RT continues to attract a wider range of potential users that can appreciate its benefits, while overlooking its shortcomings.

Many moldmakers that employ rapid tooling techniques can produce relatively simple molds in days, rather than weeks. In an increasing number of cases, rapid tools are being produced in the same time is takes others using conventional methods to quote a mold. Production runs from 10,000 to 20,000 parts in materials like glass-filled nylon and polycarbonate are becoming more common. Admittedly, tolerancing with rapid tooling techniques is still not as tight or predictable as it is with machining, but new developments in design software, tooling technologies, and construction materials will improve accuracy while providing new tooling opportunities.

RP can also reduce tooling bottlenecks by eliminating the need for prototype tooling. This, time saver, however, requires stringent mechanical design and analysis practices. Then the rapid prototyped part can be used to check form, fit, and function with the results being incorporated into the production tooling.

Acceleration Through Simulation and Analysis

Simulation and analysis are no longer the domains of just a few dedicated specialists as more of each is performed earlier and more often in the mold design process. Simulation, though, especially mold filling, is still considered something of a luxury, as it is only applied to especially challenging projects, as opposed to a majority of projects. Not helping matters at the moment is the perception that simulation is not always as accurate as it could be, but simulation and analysis results are improving when compared with real world results. Because these tool are used before a tool is cut, their major benefits include improved product quality, faster time to market, and money savings.

Today's sophisticated simulation packages are a far cry from those of just a few years ago where often all they could provide were "best guesses" as to if a mold would fill properly for a given part design. Newer analysis products, such as Moldflow's Plastic Adviser series is comprised of packages for analyzing both molds and parts. It can be used for optimizing production as well as providing insight into the probable quality of resulting parts according to a given set of parameters and variables. Other available tools have the capabilities for gate placement and gate size, material selection, and processing conditions, as well as predicting sink marks and other cosmetic defects.

Generally, most moldmakers are advised to get into simulation and analysis slowly over the course of two to three years. In the beginning, it is often most cost effective to outsource some of the most complex work to a consultant as you develop in-house expertise. It's only when the benefits of relatively simple mold filling simulation and analysis are measured and realized should a company advance to such areas as warpage and cooling. Finally, it's essential that simulation and analysis results are properly communicated and acted upon. Interoperability Challenges and Improvements Interoperability, the ability to translate and understand files from different CAD/CAM systems, is today probably still the number one challenge (and headache) that moldmakers face.

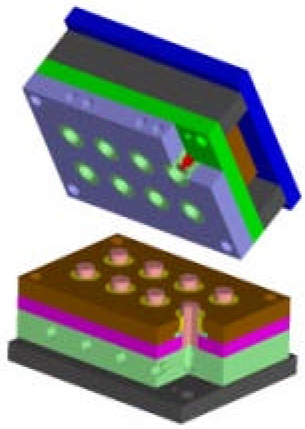

image courtesy of Cadkey

Although many CAD packages are used by moldmakers, the two most popular today seem to be

AutoCAD, SolidWorks, or a combination of the two. Pro/ENGINEER and Unigraphics come next, followed by SDRC I-DEAS, Mechanical Desktop, and CADKEY. It also appears that 3D is finally overtaking 2D as the preferred environment for design and communication. Yes, even though it is the year 2001, there is still a debate about which is better for CAD in mold design - 2D or 3D - and there is still a good degree of resistance to make the transition. Why? Primarily, because 2D as a means of communicating designs has been around for thousands of years. Many moldmakers feel, however, that 3D lets them avoid problems before any real money is spent on tool making or manufacturing.

Repairing imported CAD models remains the crux of the interoperability problem. Often, problems stem from the fact that the originating CAD system and the one receiving the data for CAM are different. A designer sends CAD files out to suppliers for CAM work. The file is sent in a neutral file format, such as IGES, and imported into a supplier's CAM system. When the supplier tries to use the imported file, a variety of errors are found in the 3D model, ranging from missing and duplicate surfaces to gaps. The time wasted with rebuilding these models is a major expense in terms of both time and money.

Unfortunately, most CAD models built today cannot be used by downstream applications such as CAE packages without performing some type of gyration. However, there are now packages and services available that, through an automated process, attempt to repair problems. If these problems cannot be fixed automatically, the specific problem areas are graphically displayed, and customers are led through a step-by-step manual repair process.

Neutral file formats, such as STEP and IGES for data exchange are not without problems of their own, and where possible, if you can't use integrated and related products from a single vendor, it's usually best to use a native-to-native CAD translator, bypassing the neutral file stage.

While IGES and other popular data exchange standards, such as STEP, VDAFS, STL, etc.) provide a neutral file format, the translation process can still be prone to problems, where errors occur when a system's translator is interfaced with the IGES format. The IGES specification is open to interpretation and vendors developing their own IGES translators often make judgment calls as to the meaning and definition of IGES rules to their own advantage. As a result, IGES translators can vary widely from vendor to vendor.

Conclusion

Moldmaking is a very demanding profession and isn't expected to get any easier anytime soon. With ever-increasing pressures to reduce time and cost and get products to market quicker, moldmakers would be well-advised to explore and exploit any technological advantage they can. Those that embrace new technologies and use them to their advantage will likely thrive, while those that don't may find survival a difficult task.

Comments? Feedback? Click here to tell us what you think about this topic or if you have additional information you'd like to share on this subject! Jeffrey Rowe is an independent industrial design and technical communications consultant. He can be reached at jrowe@cairowest.com.