Advanced Mold Making & Special Mold Making Techniques

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Before discussing some “Advanced Mold Making and Special Mold Making Techniques”, it is necessary to review some of the basics involved in tooling a job. Without a sound and through understanding of the basics, no advanced mold making technique can be successful. To paraphrase an old computer programming saying; “garbage in, garbage out”.

Some of these basics do not involve the “hard end” part of the task such as material selection, design and engineering but the “soft end” such as customer expectations, employee training and routine inspection, care and maintenance.

I have broken down “The Basics” into several categories or cases to make it easier to understand and hopefully become part of a check list for new tooling projects. There is no substitution for clear thinking and organization when taking on a project or task of making tooling.
Customer Expectations

Case 1: Fast Turn Around

In this case, speed is essential and cost is of little or no object. A common scenario is a customer who is on a deadline for producing a product or a new model. Examples of industries that do this year in and year out are automotive, defense and recreation. It is very common for projects like this to run late for all kinds of reasons- none of which are your responsibility. But we all know what flows downhill. Your phones rings, and your customer demands/begs for a few parts in 96 hours and cost is of little concern. However, time is. If you can meet his deadline you are a hero; if not you are a bum!

It doesn’t take a rocket scientist to figure out that this is a grand opportunity to make a decent profit, gain customer respect and gratitude as well as position you to go after other “routine” business. Believe me, if you succeed in meeting these seemly impossible deadlines, doors open, attitudes change and sales barriers disappear. The question is:” How do I do this?”

The answer is Rapid Prototyping (RP). Much more on this technology later.

Case 2: Low Cost

The demand by customers for low cost tooling is, by far, the most common case. Too many customers only have a vague idea of how important good tooling is to the final product- not only for fit, form and function but production efficiency. Good tooling is a critical component for making all this happen and it does not have to be costly.

Two technologies or methods exist to solve this problem – urethane tooling and an internal machine shop equipped with a few basic metal working machines.
**Case 3: Dimensional Accuracy**

This is a tough one. Many purchasing agents and sadly too many engineers, who should know better, think of cast urethane elastomers as metals and treat cast urethanes according. They have overlooked the fact that cast urethane elastomers (or more correctly urethane elastoplastics) are not rigid bodies and urethane have a coefficient of thermal expansion roughly 10 times that of most common metals used in industry.

Reinforcing this observation is the sad fact that many drawings submitted to urethane shops come on the standard plate with a preprinted title box. Almost always they come with a standard dimensional tolerance table that is preprinted and intended for metal components.

Read the customer’s print very carefully and note in the title box the dimensional tolerances. In the special case of a rotating component, look for TIR or Total Indicated Runout. This is a measure of how close you are to a perfect circle the OD of the rotating part creates as it revolves a full 360 degrees. Tight tolerances dictate the use of metal tooling, thus eliminating the consideration of urethane, epoxy or fiberglass tooling. Too tight of dimensional tolerance on TIR will force you to cast to near net shape and machine down to the final diameter.

**Case 4: Critical Surfaces**

Critical surfaces are defined as those surfaces whose integrity will determine if the part will function properly or fail prematurely. When reviewing a print, make sure you and your customer understand completely what is a critical surface or edge and what will be the result if failures occur at this location. It might be of little or no consequence; it could lead to an immediate and very costly shutdown of some piece of critical equipment or (in the worse case) risk injury to humans.

A good example of this is urethane coated knife gate valves. The urethane coated knife gate lip must seal completely with its mated surface. This means that the urethane sealing lip must be completely filled with urethane-no air bubbles or voids are allowed. This requirement dictates metal tooling with good heat transfer characteristics and attention to how the liquid urethane mix is introduced into the mold and how air is vented.
Case 5:  Appearance

Just about all consumer products made from cast urethane demand almost perfect appearance—no bubbles, no mixing striations, uniform color and a clean surface. Some examples of such products are skateboard wheels, boat trailer rollers, golf putters and urethane covered weights. In each case, the customer (you and I) choose the part we will buy very carefully. After all, it is our money we are spending on our on pastime— we want something that performs well and looks good.

Just about any type of tooling will meet these requirements if certain basic standards are adhered to. More on this subject later.
General Considerations

The following applies to low tech as well as high tech tooling.

1) Marginal Part Design + Marginal Tool Design = Disaster

2) Design tooling for ease of handling in the shop. Remember, you are dealing with hot molds requiring gloves to safely lift position, demold and reassemble. Center of gravity, total weight and handles or gripping points are important factors to consider when designing tooling.

3) Design tooling with the following key features in mind: Opening, demolding the part and reassembling. As stated above, you are dealing with hot molds with gloved hands. Clamps or other fastening techniques must be big enough to be grasped with a gloved hand. Socket head screws and allen wrenches are not acceptable in the vast majority of cases. They are just too small and clumsy to handle efficiently in a shop environment.

It is critical for tooling to be designed to accept inserts in the correct manner. That is to say, the hot insert must be able to be placed in the mold in the correct position the first time it is loaded and stay properly positioned during the complete molding process- mold closure, reheat and pouring. Furthermore, molds must be designed to be reassembled in one and only one way. Reassembly may seem simple to you or to some of your more experienced shop personnel because you have done it before. But to the new guy or greenhorn, it is a puzzle. If it can be done wrong, it will be done wrong. More often than not this will not only result in rejected parts (hopefully caught by your internal QC system and not by the customer) but missed critical deadlines and angry customers.
4) Demolding Considerable thought must be given to exactly how the part is to be removed or demolded from its mold. You must remember that demolding is frequently rushed- everyone wants the shortest demold time for obvious reasons. This means that the urethane elastomer is still in a tender state, lacking good mechanical strength. Good mold design will take this into account allowing compressed air or gravity to assist in an efficient demolding process. Urethane shrinks, of course, making it difficult to remove from a mandrel- the longer the mandrel, the more difficult it is to demold a part. This is where compressed air assisted demolding shines. Done right, parts can be literally popped out of a mold without touching it.

Another trick of the trade (if dimensional tolerance and end use application permit) is to design into the mold a 1 ½ to 2 degree taper in the OD of a tubular shaped part. This greatly eases the stress place on the part about to be demolded by forming a cone instead of a perfect straight wall cylinder. Perfect cylinders tend to form a vacuum in the base of the mold as the part is being pulled from the mold, making it very difficult remove an undamaged part. This very slight taper breaks the vacuum at the very beginning of the demolding process. Yes, the OD of the part is not a perfect cylinder in the literal sense of the word, but if done properly one end of the cylinder is on the high side of the specified dimensional tolerance, the opposite end is on the low side. In most cases, these few thousandths of an inch

Differences have no meaning, are never noticed and will quickly disappear when the part is installed and “breaks in”.

**Advanced Tooling**

Now for the good stuff. I am going to treat all tooling as advanced tooling because there is always a high tech element in everything. Just as word processing, spell check, E-mail and faxes have changed how we create and distribute written documents and engineering drawings, so have commonly accepted tooling practices. We have come a long way from typewriters, correction fluid and mimeograph machines. We have also come a long way from urethane mold, manual lathes, vertical mills and cut off saws.
Urethane Tooling
Thermoset cast urethane in the 90A to 60D durometers range have a unique set of physical properties that lend themselves to not only make a wide variety of parts but also tooling. They are strong, slightly flexible can take repeated hot and cold temperature cycling, are ding and dent proof and can be cast into complex shapes. They are, and this is important, readily available on the shop floor and cheap.

The typical urethane mold can be a single piece or multiple piece tool cast around a pattern. The pattern can be made from metal, urethane or wood. Yes wood. Dried mahogany, sealed properly and mold released thoroughly can be used as a pattern to make simple urethane molds for such items as classifier shoes and belt scrapers.

Aluminum is by far the most commonly used material to make masters for urethane tooling. It is readily available and is ease to machine. Like any other material used to make masters for urethane tooling, it requires a “break in period”- that is- it must be heavily coated with concentrated release agent (the most commonly used is silicone oil concentrates) and baked in for 24 to 48 hours before being put into service.

The obvious advantage of urethane tooling is once the master is completed and the mold made from it checks out and is signed off, several molds can be made in a very short period of time. Very often it can be put on the production line and worked into your schedule. In a few days you will have several molds made a low cost that can quickly complete a job that would take considerably longer to do with a few more expensive metal molds. Another advantage is if a urethane mold gets damaged just throw it out. It didn’t cost much, it is easy to replace and because you have several urethane molds in process, one less mold will only minimally effect production.

Depending on several variables, typical urethane tooling run under normal conditions can last about 200 cycles. They do have a tendency to build up mold release residue and strong solvents can destroy them. Never soak any urethane mold in any solvent to remove mold release buildup.
Fiberglass Tooling
Fiberglass tooling has the advantage of being very light weight, strong, rigid and capable of being used to cast large and some times weird shaped components. The process starts out with a wooden master or pattern coated with a proper release agent. Then at least two coats of a gel coat is brush applied and allow to cure. Then a polyester outer coat of resin is applied and while still wet. Layers of precut fiberglass cloth are rolled into the curing resin. Bear in mind that the pouring gates and vent holes and clamping surfaces/ sealing lips have already been designed into the mold. After curing, the pattern is carefully removed or in some cases chiseled out. Yes, this does destroy the pattern.

Light weight fiberglass tooling can be designed to accept heavy inserts but they must be well supported. Care must be taken everyday use of fiberglass tooling. Dropping a heavy insert can crack the mold; careless use of demolding tools can chip the critical gel coat. Both of these are very difficult to repair. Also it is almost impossible to modify fiberglass tooling- such things as opening up vents, changing sprue hole size and location, change internal surfaces to accept an insert dimension change.

Fiberglass tooling is light weight, thin ( usually no more than 3/8 inch thick) coated on the inside with a hard, almost brittle gel coat than can produce very smooth complex surfaces. It must be treated with respect during use as well as storage. Do not drop fiberglass tooling!

For large, complex items such as closed centrifugal slurry pump impellers, fiberglass tooling is much cheaper than metal molds and most like can be made with in a few weeks instead of the typical few months it takes to get a metal mold made. Fiberglass tooling provides a means of getting into a business where very expensive metal molds present a significant entry barrier. Fiberglass tooling can be considered semi-permanent tooling.

Rapid Prototyping and Tooling
There are host of technologies that combine several supporting technologies that can produce some amazing results with respect tooling. They are based on additive material principles (objects are built layer by layer) not by a subtractive process common to every machine shop practice. RP technologies are highly computerized and frequently reply on laser and photochemical technologies.
Stereolithography (SLA)
Stereolithography has been around a few years but has just recently come into its own. This technology combines three (3) technologies into a single coherent package: laser, photochemistry and computer.

SLA starts with a 3D CAD data that describes the physical dimensions of the part (master) you want to make. It must be perfect. The 3D data is then loaded into the SLA computer. The machine builds the part layer by layer by using a special laser to cure the liquid photopolymer. This process is done on a “stage”- a vertical moving platform that supports the newly created part or master. After the laser has completed its task of curing a layer, the stage is lowered slightly; liquid photopolymer covers the newly created solid layer and the laser traces the next surface. And so the process goes on, unattended, for hundreds of cycles until the object is completed.

It is then removed from the bath and washed to remove any liquid photopolymer and lightly sanded to smooth out the edges. You are ready to go- that is- to use this mater to cast urethane, epoxy or silicone molds.

A little common sense needs to be applied when handling SLA masters. They are not bullet proof- be sure to mold release them properly before you make your first mold. Be very careful if you choose to include on your SLA master vent stacks and spurs.

A new twist in SLA technology is nickel plating. After the SLA master is made, cleaned and finished (sanded) it can be nickel plated. No only does this produce a mirror finish, but it can increase its strength and stiffness. It also makes it virtually water proof. Uncoated SLA masters can increase in size as much as 2% over a long period of time if stored under very humid conditions.
**Selective Laser Sintering (SLS)**

Selective Laser Sintering is a close parallel to steroelithography. Instead of using a liquid photopolymer, the working material can range from wax to certain nylons and even metals. Just as in SLS, a 3D program describing the master is loaded into the machine. A thin layer of powder is then applied to the stage. Next, a laser is traced over the powder fusing it to a solid layer. The Stage is lowered slightly, a roller applies another very thin layer of powder and the process repeats itself over and over again until master is complete. Just as done with SLA made masters, the part is removed and cleaned up.

The advantage of SLS made masters is that they are made from more durable materials and therefore more robust.

**Polyjet (Objet)**

Polyjet technology takes advanced tooling a step further. Again, you start with a 3D CAD program that is fed into the machine. Again the polyjet machine has a stage that can be raised and lowered. The heart and soul of Polyjet technology is the special ink jet (developed and modified from the inkjet on common printers). The Polyjet special ink jet has a UV laser built into it. A photopolymer is sprayed through the inkjet onto a support mounted on the unit’s stage. As the inkjet head moves about, describing the layer to be built, the UV laser instantly cures the photopolymer. Layers as thin as 16 microns (0.0006 inch) have been built buy this technology.

Because this technology is still very new and somewhat costly, its nitch (for now) seems to be for small parts requiring fine detail.

Polyjet technology has another area of application- something often called desktop manufacturing. I think you can see where I am going with this concept. A customer sends a 3D CAD drawing to a vendor who has a Polyjet machine. The machine makes the final part (not the master). For now, only ABS and TPE photopolymers are available, limiting what can be made. Given that many companies world wide are working very hard to improve and extend this technology, I expect amazing things to happen in a short period of time.
**Fused Deposition Modeling (FDM)**
Fused Deposition Modeling is a lot like Objet. FDM uses a plastic wire-like filament unwrapped from a supply coil. And is fed to a heated extrusion nozzle equipped with an on-off valve. The nozzle is mounted on a computer controlled mechanical stage that can move in the X-X, Y-Y and Z-Z planes. The heated nozzle, controlled by the CADS software package moves in horizontal directions depositing the liquid polymer. In a manner similar to SLA, the master is built up layer by layer as the polymer very rapidly solidifies as soon as it leaves the nozzle.

Several polymers are available to be used with this technology, allowing for trade-offs between strength and service temperature. They include ABS, ABSi, polyphenylsulfone (PPSF), polycarbonate and even some plastic alloys as PC-ABS. Thus, masters or prototype parts can withstand rough handling and even functional testing. However, FDM process, as of the present does not yield a fine detailed product - it is good enough for shop use but not quite good enough for a display model of a consumer part.

**Electron Beam Melting (EBM)**
First developed by Arcam AM of Sweden, this technology uses a high energy, precisely focus, electron beam to melt very fine metal powders layer by layer. The process is done in a high vacuum chamber. The resulting product is solid, void free, and does not require additional thermal treatment. Compared to other rapid prototyping technologies, EBM, because of its higher energy density and scanning method has a faster build rate. EBM not only can build high definition masters, but the product itself.
Summary

As you can see from the above examples and brief descriptions, we have an overwhelming choices of RP technologies. What’s more, these technologies are advancing rapidly on a world wide basis. A multitude of widely diversified industries from medical implants to automotive to recreation recognize the potential of RP and are adapting it for several reasons: cut development time and cost, to get ahead of the competition, to distinguish themselves as a technology leader and to improve the overall efficiency of the organization.

The big question remains: how do I tap into this technology and make it work for me? The answer is not difficult:

**Step 1** Go on line and Google “rapid prototyping” or other similar topic. Download and read everything you can.

**Step 2** Contact a number of the companies that offer these various technologies and discuss, in detail, your operation and where you think this technology could fit into your organization. Ask what infrastructure is required - computer, software and trained personnel to run it. Ask if they have a demonstration or promotion CD that explains the process details. Get a clear understanding of cost.

**Step 3** Ask for a sample that you can use for a master to make a few urethane molds. This will give you a feel of how this technology works in your plant run by your people. Most of these RP companies have obsolete models in their “boneyard bin” that could be used as masters that would help you learn this technology. Just be sure to return the sample when you are through using it.

**Step 4** after you have narrowed your choices; request a visit by a qualified sales engineer of one or more RP companies. Prepare an agenda and send it the engineer so he may prepare a presentation that answer your questions and addresses your concerns.

**Step 5** Make a list of pros and cons. If the pros out weigh the cons, do it! Go slow at first- don’t over commit. All new technologies when first introduced to a company take time to be digested and demonstrate their payout.
Finally, please keep in mind that things always change, technology marches on. Do you want to join the parade or be left behind? Rapid Prototyping (RP) is an additive fabrication technology. Objects are built layer by layer using a wide variety of materials using similar techniques. The old way is subtractive technology, whereby machines remove material from a starting block to produce an item.

RP is eliminating distance as an impediment in doing business. 3D CAD data is sent to the RP house instantly via the internet where they are reduced to a set of numerical, instructions for the RP machine. A part (master) is quickly produced and returned to you. Curiously enough, next day package service can be the time limiting factor in this whole process— it takes a day to ship the master from the RP shop to your facility and another day to get it to your customer.

I do expect in a time shorter than most of realize the RP cost will come down to the point where many urethane facilities will have one of these units on site just as they now have sophisticated urethane dispensing machines and CNC machine centers.
Appendix 1

Technologies That Almost Made It

**Spray Metal Mold Technology (SMMT)**
Spray metal mold technology is an interesting but seldom used technology to fabricate molds. It is still available but seems have been displaced by SLA and other similar technologies. In this process two electrically isolated wires are fed into a special spray gun at an intersecting angle so that the wires come into contact with each other. The resulting electric arc melts the wire ends and molten metal is atomized and sprayed on the master surface where it rapidly solidifies into dense metallic coating. After the master is coated with metal, it is backed up by a rigid tooling epoxy. SMMT never really took off - there were too many problems master damage or warping during the spray operation, operator technique, coating consistency, etc. to make it widely acceptable. Spray Metals Molds Technology, Inc of Marshall, MI is one of the few companies that still use this technology.

**Wash Out Tooling (WOT)**
WOT is a clever and unique solution to a vexing problem - how do you mold a hollow component when the design prevents you from removing a mandrel or center part? The answer is making the mandrel out of a sturdy material that is water soluble. One variation of WOT is a mixture of sodium nitrate and sodium nitrite salts, some silica flour and a couple of other inorganic materials. This forms a low melting matrix that can be cast into what ever shape you need. This is then placed into the mold and urethane cast around it. After curing, the outer portion of the mold is removed and warm water is used to dissolve the interior or WOT portion of the mold.
The drawbacks of this technology is that the WOT in its dry form is a powerful oxidizing agent and must be stored and handled carefully by trained personnel. As a cast ceramic, it is somewhat fragile and must be handled carefully. It is a one time use only item although some companies have gone through the trouble of recovering dissolved WIT. WOT produced a rough surface: in most cases this is of little importance since it is hidden from view. And there may be a disposal problem. Nowadays there are very strict rules of what can and cannot be flushed down a sewer drain.

**Thermoplastic Molds**
A very few companies use polyethylene or polypropylene thermoplastic injection molded molds to make large quantities of small, simple parts. Both polymers have release qualities and reduce or almost eliminate the need to apply conventional release agents. However, these polymers are operating on the edge of thermal stability (warping under exposure to heat). Mold cost can escalate substantially as complexity of the part increases. The tooling used to make these molds can be expensive.