LIQUID RESIN CASTING™
Polymer Corporation

THE PROCESS

Casting in plastics is based on mixing and then pouring resins that are liquids at or near room temperature into various types of molds, and through chemical reaction and usually with the addition of heat, allowing them to cure (solidify). These materials (thermoset resins) undergo an irreversible reaction.

While the process can be automated to some degree, it has its greatest commercial value in prototyping and low volume production. The trade offs, compared to high volume methods such as injection molding, are lower tooling costs, higher unit costs, and a generally shorter tooling cycle.

The greatest economic benefits occur with unusual geometries that are too costly to machine and annual volumes that are too low to justify the expense related to injection mold tooling.

Most casting resins are low enough in viscosity to pour readily into molds without the need to force them in under pressure. In addition, the temperatures required to effect an initial cure are typically 150-200°F. These relatively mild processing conditions allow for the effective use of non-traditional mold media, such as RTV silicone. Other mold materials commonly used include steel, aluminum, epoxy and polyurethane. These materials can be used in combination with each other to take advantage of their individual attributes.

Insuring that castings are cured without porosity requires the use of vacuum degassing procedures or other techniques such as centrifugation. Vacuum degassing, coupled with other procedures, offers the greatest flexibility in dealing with parts of different sizes. A prerequisite for vacuum degassing is that a material must remain liquid during the entire procedure. This typically means a resin must remain liquid for 30 minutes or longer before hardening.

Most formulations of this type need 10-12 hours to complete their initial cure. As a result of this requirement, most molds are limited to one cycle per day. Typical production runs entail the use of multiple copies of molds to support the anticipated production rate. To allow the production of more parts from a single mold during a day, quick-set resins increasingly are being employed. Some of these resin formulations harden in a minute or less.

THE MATERIALS

A common misconception of manufacturing and design engineers is to assume the performance of a particular material sample will be, more or less, the same for all formulations in that class of compound. Nothing could be further from the truth. Each formulation has a unique set of processing attributes and final cured properties. The priorities of a prototyping application are quite different from those associated with the final production version. The pace of materials

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development today is brisk and accelerating. The best recommendation for a material that is required to perform a given job will come from the processors and suppliers of these materials.

EPOXIES are among the group of materials that have been used in commercial applications the longest. They continue today to be at the forefront of materials technology, where they are used extensively as the backbone in resin in composites. Epoxies are available in several forms, with the primary suppliers being Dow Chemical, Shell, Union Carbide and CIBA Geigy. Epoxies are available in standard Bisphenol-A, Novolac, and Cycloaliaphatic grades as well as others. These are combined with various curing agents, accelerators and fillers to produce an almost infinite variety of compounds.

To give a sense for the diversity of these compounds, formulations are available to produce parts that will be: clear, translucent, corrosion resistant, capable of withstanding 400-500°F, compliant with FDA guidelines for wet or dry food contact, implantable in the human body, high voltage resistant, high strength flotation devices, microwave absorbing, microwave reflecting, autoclavable, etc. By the creative combination of basic epoxies, curing agents and various fillers, selected properties can be enhanced to accommodate a broad range of end use applications.

Epoxies find their greatest use in applications where they must survive in a harsh environment. They are, for the most part, highly crosslinked resins, which account for their ability to withstand extreme conditions. However, because they are highly crosslinked, they tend to be somewhat brittle. Thoughtful designs will not incorporate thin sections that might be overly stressed. Successful parts designed with epoxies tend to be thick walled "chunky" parts, using generous fillets and radii to eliminate stress concentrations.

POLYURETHANES have as their greatest assets their toughness and abrasion resistance. Where epoxies are very hard and brittle, polyurethanes are available in hardnesses ranging from Shore A-10 (soft rubber) to D-85 (hard plastic). In the hardness range of D-75 and softer, these materials are capable of handling standard drop tests and other more violent assaults. The softer the compound, the greater is its ability to absorb energy without breaking.

Polyurethanes have several different forms, including polyether, polyester, polybutidiene and aliphatic based systems. Polyurethanes can also be successfully blended with other resins (such as epoxies). This "Alphabet Soup" of chemistries provides the designer and custom processor ample opportunity to be creative and take advantage of the diversity and full capabilities of polyurethanes.

Applications include: instrument cases, decorative bezels, hand held surgical devices, gaskets, cable strain reliefs, pulleys or slides, protective bumper strips and holders, fluidics devices, high voltage components, marine fittings (thru hull, propellers, shrouds), lenses, electronics packaging, encapsulations and almost anything else that can be imagined.

Polyurethanes do have their limitations. They generally are not suitable in applications requiring elevated temperatures (above 200°F), nor can they withstand the broad range of chemical exposures that epoxies successfully handle.

SILICONES represent the only inorganic compound that is currently castable. The major U.S. suppliers are Dow Corning and General Electric. The RTV (room temperature vulcanizing) versions are what is most commonly used; however, other types of silicones requiring heat and moisture to cure are also castable.

The three major attributes of silicones are: 1) their ability to withstand temperatures as high as 600°F, 2) their flexibility and hardness remaining relatively constant over a broad temperature range (this is especially significant at temperatures well below freezing), and 3) the inherent inability for any material to stick (bond) to them.

Typical applications for silicone castings include: strain reliefs for surgical devices (high flexibility and autoclavability), gaskets, and seals.

TOOLING TECHNIQUES

Tools can be conventional metal molds (aluminum, steel or brass) machined as one or more cavities, or quite unconventional RTV silicone molds often times used in combination with metal or plastic cores. Other mold materials used include polyurethane, epoxy, and fiberglass. The key, as in material selection is, "what is trying to be accomplished?".

SILICONE MOLDS offer the advantages of producing high quality finishes (release agents are normally not required), casting in modest undercuts without side action and maintaining reasonable tolerance control (±.004"/inch). These molds are created by pouring RTV silicone rubber over patterns or models of the shape of interest.

Production requirements necessitate patterns being made of aluminum, or some other suitable metal. This class of pattern will not wear out or change shape with time. As a result, this will allow for unlimited quantities of molds and parts to be produced, while maintaining the greatest control on dimensions and general part quality. Plastic or wood patterns can be used, but may warp or distort with time. This limits their use to prototyping applications.

While a sizing factor is normally applied in the creation of a pattern, the difference between the original and the subsequent castings can be insignificant in small to medium size parts. This provides the opportunity to utilize existing parts as the basis for "tooling". The shape of the part, as well as the require tolerances and appearance, will determine how valuable an existing piece will be. Applications that require cores to define key details will not result in the same cost and time savings as those that can be made directly from a part. Casting processors can advise on the value of the existing part in the tool up process, on a case by case basis.

A major advantage in using aluminum and silicone molds in new product development is the relative ease with which changes can be implemented. Many designs start in one form but evolve as they undergo the tests of manufacturability and exposure to the marketplace. Existing tooling is rarely scrapped unless changes are very radical. This gives the ability to go to market with the most desirable product possible.

In production, it is common practice to run multiple quantities of silicone molds to increase the rate of manufacture of a part. Selected part details can be defined by metal or plastic cores (to reduce cost or improve tolerance control) or as a machined secondary operation. If the number of machining operations becomes extensive, other mold materials (metal or plastic) should be considered.

METAL MOLDS are capable of maintaining tolerance control to ±.001"-.002"/inch, with excellent flatness and parallelism of surfaces. As parts increase in size (above 300 sq. in.), the unit cost of parts produced in metal molds becomes increasingly more favorable compared to the same part made in a silicone mold. This is due to the fact that silicone molds wear out and their cost is generally amortized into the part cost.

Finishes are limited to a semigloss, as release agents are sprayed on mold surfaces to insure parts can be removed properly. Draft may be required on parts that have an exceptionally deep draw.

Careful production planning is required to match production rate with the proper number of molds. Excess metal molds produced will add unnecessarily to the total tooling cost.

EPOXY/POLYURETHANE MOLDS provide a blend of some of the advantages as well as some of the disadvantages of silicone and metal molds.

The ability to make multiple copies of molds fairly inexpensively is similar to the silicone mold approach, but the quality of appearance is the poorest of all the mold options available. Initial tooling starts with a metal pattern, then a suitable cast resin is poured over the pattern to create a mold. The pattern will not be affected by the casting process, so as many molds as are required to support the production plan can be produced.

Surface finishes are semigloss because release agents are necessary. Tolerances that can be maintained are typically ±.002-.004"/inch within a given mold. As additional molds are produced, each one is slightly different. The larger the part, the more significant this variation becomes.

These molds can wear out or even break with repeated heating and cooling. Replacement of molds may have to be considered in certain programs. Large parts (any single dimension over 40") may be more economically produced by creating a wooden model and then producing a laid-up fiberglass mold. Parts of this type pose unique processing problems that can only be addressed on an individual basis.

DESIGN CONSIDERATIONS

Pouring free flowing resins into flexible silicone molds provides more opportunities for a designer than obstacles.

SILICONE MOLDS offer many unique design advantages. They include the ability to cast in modest undercuts without any side action. Some of the more flexible versions of silicone will allow a 1.50" diameter part to be extracted from a 1.00" diameter opening. Contoured handle grips can be made without any parting lines, "door knob" type features can be cast integral with a panel or tray. This particular advantage often times allows a designer to combine two or more parts into one, potentially achieving meaningful cost savings over optional manufacturing methods. Extreme undercuts or openings can be accommodated by using multipart molds.

REPLICATION OF FINE DETAIL is another benefit of using silicone as a mold material. If the detail is on the pattern, it will appear on the parts. This allows casting in almost any finish that is appealing. Typical cast finishes include: high gloss, sand blasted, sanded, or textured surface of any combination. The key is to have the original pattern look exactly as the finished part is to appear. Textures can be applied by painting the pattern or chemically etching the surface (i.e., producing a Mold Tech ™ type finish).

TOLERANCES that can be achieved with silicone molds are based on a number of factors including: How many parts do you attempt to run from a mold? What is the mold material? What is the resin you are running in the mold? Is it a one part mold with a straight pull or a two part mold? Another factor that can influence tolerance is casting around a large metal component.

At Polymer Corporation, our experience is that you can plan on holding ±.004"/inch on most dimensions. In the evaluation of a design, if a dimension needs to be held to a higher tolerance than this, it should be defined by something other than silicone. Typical options would include defining the detail by aluminum or steel (a critical diameter would be defined by a metal core pin as an example) or machining the feature as a secondary operation.

SELECTED PROCESS ADVANTAGES are independent of the kind of mold material used. Wall thickness variations can be cast without any concern for sink marks or other blemishes with the use of slow curing resins. Additionally, thick or thin wall sections can be cast almost without limitation. However, the ability to create a detail does not mean it will function as intended. The best recommendation is to consult with an experienced supplier about the feasibility of a particular design detail.

CLEAR FORMULATIONS are available in all classes of casting resins. These systems can be tinted with organic dyes to achieve custom tints at various levels of intensity. Some formulations will darken (or yellow) with time, principally due to UV exposure, while others remain clear. This color shift has no effect on physical properties other than the slight change in visual appearance.

CUSTOM COLORS can be achieved by blending in various pigments to any resin formulation. This ability to cast color and finish into a part can save time and money by avoiding the need to paint as a finishing procedure. Should a product be accidentally scratched in a customer's hands, it will continue to show the desired color, thus maintaining a higher quality of appearance. If products require a highly professional appearance, these techniques can be used quite successfully.

Some limitations in providing custom colors should be noted. The base color of some casting resins can be dark brown, making these systems inappropriate for use in applications calling for white parts. Also, the daily batch processing nature of casting (1-10/day is typical) leads to a wider variation in color than processes such as painting or injection molding where parts are processed at one time. Resin formulations that set very quickly offer additional challenges.

A designer should not plan on using custom colored cast parts if they are to be used immediately adjacent to molded or painted parts with a matching color requirement. The results will be disappointing. Parts in this situation can be cast in a complementary color, where slight variations will not be noticed, or if this is not possible, they should be painted with the matching parts.

DRAFT is never required on exterior surfaces, even with metal molds. Internal draft is only necessary in very deep draw applications where rigid cores are used. On occasion, we have even cast reverse draft holes using core pins.

INSERTS or other foreign components are cast into parts routinely. Often times, these items can be added as a secondary bonding operation more efficiently than casting them in place in the initial process. With proper technique, the retention of the inserted item is as strong as if it were cast in place.

Threaded metal inserts are available in self-tapping, expansion and "bond-in" styles. Metal threads are recommended over plastic with threads of ¼-20 or smaller are planned and multiple assembly and disassembly of the unit is anticipated.

CASTING LOGOS or other graphic detail into a part lends a certain elegance to the appearance of an item. These can be subsequently filled in with a contrasting colored resin to make the graphics stand out if desired.

EMI/RFI SHIELDING requirements are best accomplished by painting a conductive coating (such as the copper or nickel types) on those surfaces of interest. Adding conductive metal flakes or fibers to achieve shielding requirements is impractical. The loading level of flakes and fibers necessary to achieve a minimum level of shielding effectiveness increases the viscosity of the liquid resin to such an extent that you cannot pour a high quality casting.

Lower levels of conductivity that are adequate to provide electrostatic discharge (ESD) protection can be accommodated by adding specialty compounds to the resin.

CONCLUSION

Liquid Resin Casting™ offers the low volume manufacturer an opportunity to create and execute first class designs while minimizing the capital outlay and risk often associated with producing tooling for high volume molding techniques.

A wide range of formulations, tooling techniques and compatible secondary operations (machining, assembly, painting and decorating) provides for the successful manufacture of parts across a broad range of application areas.