A Guide to Rotational Molding

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Figure 1. Various rotomolded toys

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Introduction

Rotational molding – also referred to as rotomolding or rotational casting – is one of the fastest growing plastics processing methods today.

It's easy to see why. Rotational molding techniques – coupled with Microthene® polyolefin powders from LyondellBasell – can be used to make hollow items of any size, open or closed, and of any desired shape.

In recent years, rotomolding techniques have been developed extensively. On the production line, this process can now compete with or outperform blow molding, injection molding and thermoforming. In many cases, pieces virtually impossible to fabricate by any other processes can be produced by rotomolding.

Rotational molding was first developed early in the 20th century. But it wasn't until the early 1960s, when LyondellBasell replaced vinyl plastisol resins with polyolefin resins, that rotomolding gained wide acceptance.

Within a few years, the development of low and high density polyethylene specifically designed for rotomolding enabled rotational molders to enter markets where vinyl parts and processes could not compete. In the early 1970s, crosslinkable and modified polyethylene grades made their way into the rotational molding market. These new resins again opened up more new market areas, especially production of large tanks.

Linear low density polyethylene for rotomolding was developed in the late 1970s, while the 1980s brought a surge of non-polyethyl-ene resins, including nylon, polypropylene and polycarbonate for rotomolding.

Figure 2. Smaller storage bins and refuse containers are also rotomolded

Rotomolding is different

The main difference between rotational molding and other plastics molding techniques, such as blow and injection molding, are as follows:

- resin powder is used instead of pellets;
- the resin melts in the molds instead of being forced under pressure into the molds in a molten state;
- the mold has a biaxial rotation;
- rotomolding molds are less expensive because of their simplicity;
- and operating pressures are relatively low, allowing molds to be made from less expensive materials.

In rotational molding, rigid, resilient hollow bodies are formed by powdered plastic material in heated molds, which are rotated simultaneously in two planes perpendicular to each other.

The plastic particles make contact and melt on the inner surfaces of the hot molds and fuse in layers until all the powder is fused and the desired end product and wall thickness is obtained. The wall thickness is controlled by the amount of powder placed in the mold.

Rotationally molded pieces are stress-free except for slight shrinkage forces because the pieces are produced without any external pressure. Additionally, there is practically no scrap in rotational molding.

The uniformity of wall thickness can be maintained to within ±10 percent, which is better than that normally possible with the blow molding process. Wall thicknesses can range from 1/32 inch to 1 inch (0.8mm to 25mm). Most resins used in rotational molding are powders ground to 35 mesh and ranging in diameter from 74 microns to 2000 microns.

Figure 3. Rotomolded products in this photo range from 55-gallon drums to billiard balls

Typical rotational molding applications

Rotational molding permits production of a countless number of fully or partially closed items. Design versatility of rotationally molded pieces is almost unlimited.

The rigidity or flexibility of an item is controlled by the properties of the resin used (see section on Resin Choice) and by the wall thickness of the molding.

Some typical applications for which rotational molding is particularly suited include the following:

- commercial, industrial and agricultural storage tanks ranging in size from 5 gallons to 22,000 gallons;
- containers for packaging and material handling;
- a variety of industrial parts, especially covers and housings, water softening tanks, tote bins;
- numerous under-the-hood and in-the-cab automotive parts;
- hobby horses, pool tables and many other small or large toys with complex shapes;
- baby cribs, balls, dolls, and doll parts;
- display window mannequins and other hollow display figures of all sizes, and;
- playground equipment and sporting equipment such as golf carts, footballs, juggling pins, helmets, dumbbells, golf tee markers, canoes and kayaks.

Figure 4. Large storage tanks are a major market for rotomolding

Rotomolded parts are also used in portable outhouses, battery cases, light globes, vacuum cleaner and scrubber housings and garbage containers. Furniture, game housings, surf boards, traffic barricades, display cases and ducting can also be produced by rotomolding. The list above indicates just some of the possibilities. Figures 1-4 illustrate some of these applications.

Design – almost endless potential

With rotomolding, a plastics product designer can create a huge array of innovative products. Typical design concerns that are handled routinely by rotational molding include the following:

- maintaining uniform wall thickness – rotational molding can provide a more consistently uniform wall thickness for a part compared to other plastic processing methods;
- producing double-wall construction – rotational molding can provide uniform double-wall construction on parts;
- molding thicker corners – due to the process, rotomolded parts will have thicker outer corners which help strengthen the parts; and
- molding inserts, reinforcing ribs, kiss-off ribbing and undercuts – these are easily included in a roto-molded part.

Designers interested in acquiring more specific information can contact the Association of Rotational Molders, 2000 Spring Road, Oakbrook IL 60521, (630) 571-0611.

Advantages of rotational molding

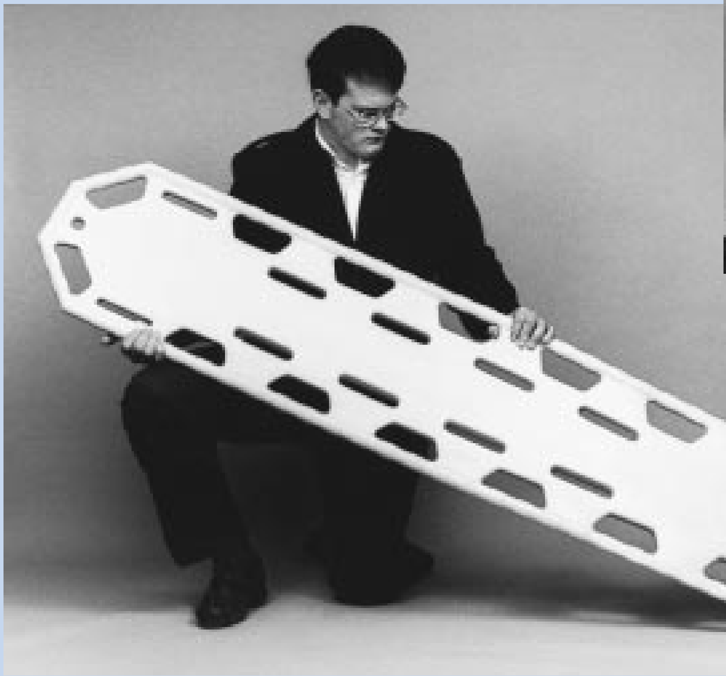
Rotational molding offers significant advantages when compared with other molding techniques or thermoforming:

- costs for molds and tooling are relatively low;
- the rotomolding technique is easily adapted to short production runs, particularly when sets of multiple-cavity molds are used;
- hollow, totally enclosed items as well as pieces with openings can be made;
- rotational molding eliminates the need for secondary tooling;
- there is little or no waste due to resin scrap;
- wall thickness and piece weight can be easily controlled;
- rotational molding procedures assure uniform wall thickness;
- deviations can be controlled to within a maximum tolerance of ±10 percent;
- pieces with intricate contours and undercuts can be easily molded;
- virtually any size piece can be rotationally molded;
- there is a minimum of cross-sectional deformation and warpage;
- rotational molding yields pieces with excellent surface detail and finish;
- rotationally molded items are virtually stress free;
- identical or similar items or different sections on one piece can be molded at the same time in different colors on a single spindle;
- plastic or metal inserts can often be molded as integral parts of the item; and
- double wall constructions are feasible.

The Race Car Bed is rotationally molded from tough, scratch-resistant, high impact strength linear low density polyethylene.

Kids are all over this seven-foot-high Big Climber gym rotomolded from weather-resistant polyethylene. The colors have been molded-in, so the parts will not chip, splinter, rust or peel.

This rocking horse comes as either a palomino or a mustang. Both are rotationally molded from polyethylene.



The spinal immobilizer board used by emergency medical services has a rotomolded, linear medium density polyethylene, outer skin and a rigid urethane foam core.

Resin choice

To obtain the desired end product, the choice of a quality powdered resin is essential in rotational molding. One reason is the high temperatures used risk chemical degradation in a less-than-quality product.

Table 1. Usage of various resins for rotational molding

RESIN	PERCENT OF MARKET
Polyethylene	84%
Polycarbonate	15%
Nylon	
Polyvinyl Chloride	
Polyesters	
Polypropylene	
ABS	1%
Acetals	
Acrylics	
Cellulosics	
Epoxy	
Fluorocarbons	
Phenolics	
Polybutylene	
Polystyrene	
Polyurethane	
Silicone	

Today, approximately 84 percent of all resin used in rotational molding is polyethylene (Table 1). LyondellBasell offers a series of Microthene poly-ethylene powders with a wide range of properties, including melt index and density. While the effects of particle size on end-product properties and processability are less critical, those of melt index and density are considerable. The main effects are shown in Table 2.

Melt Index

For rotomolding, a resin must have a good flow when molten. With polyethylene, the flow is measured by melt index. The higher the melt index, the better the flow. Most rotomolding resins have melt indices ranging from 2g/10 minutes to 10g/10 minutes. The term "g/10 minutes" refers to the weight of molten resin moving through an orifice of a predetermined size in 10 minutes.

The melt index is also a rough measure of the molecular weight or the chain length of a resin. A resin with a high melt index has shorter chains and a lower molecular weight or smaller molecules. A resin with a low melt index has longer chains and a higher molecular weight or larger molecules.

Molecular weight distribution is also important in a rotomolding resin. A narrow distribution is more advantageous, since the narrower the distribution, the more uniform the melt properties.

Density

Density is a measure of the specific gravity of a resin. The density of polyethylene is classified by types according to the American Society of Testing and Materials (ASTM):

- Type I: Low Density Resins (range of 0.925 g/cm^3 and below). Generally, low density resins are preferable whenever stiffness is not essential or is undesirable, as for many toys, and only when light loads are to be expected.
- Type II: Medium Density Resins (range from 0.926 g/cm^3 to 0.940 g/cm^3). Most linear low density polyethylene resins fall within this range. Medium density resins are useful for self-supporting items that require the higher heat-distortion resistance or stiffness that low density resins do not provide.
- Type III: High Density Resins (range from 0.941 g/cm^3 to 0.959 g/cm^3). High density resins impart the highest rigidity to the end product, which frequently permits reduction in wall thickness.
- Type IV: Very High Density Resins (0.960 g/cm^3 and above.) These resins are not currently used in rotomolding.

In addition to lowering toughness and increasing stiffness, increasing density raises the melting point, permits higher temperature limits and improves barrier properties in the end product.

Table 2. How increases in melt index and density of polyethylene powders affect processing and end product properties

AN INCREASE IN . . . . AFFECTS THESE PROPERTIES	MELT INDEX	DENSITY
Melting Point	decreases	increases
Flow	increases	remains the same
Impact Strength	decreases	decreases
Stiffness	remains the same	increases
Vicat Softening Temp.	decreases	increases
Resistance to Low Temp. Brittleness	decreases	decreases
Barrier Properties	remain the same	increase

Polyethylene powders – the workhorse of the industry

The polyethylene pellets that are normally produced in the resin manufacturing process cannot be used for rotational molding; they must be reduced to a much smaller particle size. This reduction is necessary to obtain good heat transfer from the mold to the powder.

The reduction also improves the flow of the particles during melting so that oxidation does not inhibit the moldability and development of the physical properties of the resin. The size reduction is usually done by the resin supplier, but can be done by the rotational molder who has grinding equipment.

In addition to mechanically ground powder, some resins are available as reactor powder or granules. Several linear low density polyethylenes come in powder or granular form. Some other resins such as nylon, due to its high melt flow and small pellet size, can be molded without grinding.

Polyethylenes have the following characteristics that have made them the most widely used powders for rotational molding:

- they are easily ground to 35 mesh at high rates;
- they can be made thermally stable with proper stabilization additives;
- they can be molded in high-temperature, high-speed rotational molding equipment without excessive oxidation;
- they have excellent low temperature physical properties, such as impact strength, allowing their use in a broad temperature range;
- they are relatively low in cost, making them a material to consider in all cost-effective applications;
- they are available in a wide range of densities and melt indices to fit the needs of simple, nonstressed items as well as extremely large, highly stressed applications;
- they can have their UV stability or outdoor life significantly improved by the addition of pigment or UV stabilizer;
- they may meet FDA food contact requirements; contact your LyondellBasell sales or technical service representative for more information;
- they (especially crosslinkable polyethylene) have excellent chemical resistance making them ideal for numerous large agricultural and industrial chemical tanks;
- they have high dielectric strength for use in electrical applications requiring insulation properties, such as the cherry-picker baskets used by power companies.

Table 3. Polyethylene resins: advantages and disadvantages

RESIN	ADVANTAGES	DISADVANTAGES
LDPE	Flexible Excellent warp resistance Consistent shrinkage Most meet FDA requirements 21CFR177.1520	No stiffness No ESCR
LLDPE/LMDPE	Excellent impact strength Excellent ESCR Good warp resistance More stiff than LDPE Most meet FDA requirements 21CFR177.1520	Less stiff than HDPE Lower heat deflection temperature
HDPE	Excellent stiffness Good impact strength Higher heat deflection temperature Most meet FDA requirements 21CFR177.1520	Low ESCR Warpage and shrinkage not consistent
Crosslinkables	Excellent impact strength Excellent ESCR	Longer molding cycle Does not meet FDA requirements
EVA Copolymers	Flexible Excellent cold temperature impact strength Consistent shrinkage Most meet FDA requirements 21CFR177.1520	No stiffness No ESCR Hard to mold

A new technology that produces “micropellets” can also eliminate grinding. This technology provides small-diameter pellets that, in some applications, mold similarly to powder.

Types of Polyethylene

(See Table 3 for an overview of polyethylene types)

- Low Density Polyethylene (LDPE) is flexible and tough, easy to process and has excellent chemical resistance.
- Linear Low Density Polyethylene (LLDPE) or Linear Medium Density Polyethylene (LMDPE) has better mechanical properties than LDPE as well as higher stiffness, excellent low temperature impact strength and excellent environmental stress crack resistance.
- High Density Polyethylene (HDPE) is the stiffest resin of the polyethylene family. HDPE has excellent chemical resistance and good processability.

- Crosslinkable Polyethylene (XLPE) contains a crosslinking agent that reacts with the resin during the molding cycle, forming a crosslinked molecule similar to a thermoset plastic. This reaction improves the stress crack resistance of the rotomolded part. A newer method is called electron-beam crosslinking. This process is a post-molding operation that can be done on any type of polyethylene. Many physical properties can be enhanced while the regulatory status, such as FDA approval, can be maintained.

The use of post-consumer resin (PCR) and post-industrial regrind (PIR) has become an important factor in rotomolding because of increasing concern about solid waste. LyondellBasell has performed many studies in this area and can assist you in your application.

New single-site-catalyst technology allows for the development of new polyethylene grades to meet specific needs.

Other Rotomolding Resins

Some other resins used in rotomolding are: polyvinyl chloride (PVC), nylon, polycarbonate, polyester, polypropylene, flame-retardant polyethylene, chemically modified polyethylene, such as LyondellBasell Microthene rotolining (RL) resin, and a system called one-step foam, which incorporates a blowing agent (see Table 4).

FLAME RETARDANT POLYOLEFIN

LyondellBasell has produced a resin certi-fied by Underwriters Laboratory (UL) as having a V-0 or non-burning rat-ing at 1/8-inch thickness. This resin allows rotomolders to choose from regular grades of HDPE or LLDPE rated UL 94 HB or they can use the flame-retardant resin for more strin-gent flammability requirements.

POLYPROPYLENE

LyondellBasell polypropylene resins are used in applications where higher resistance to heat distortion is required for parts requiring autoclaving or sterilization. Polypropylene requires cryogenic grinding to get a powder adequate for rotational molding.

ONE-STEP FOAM

One-step foam (OSF) is a system using several powders and blowing agent pellets to allow rotomolders to produce a part with a solid outer skin and filled with either 2, 4, 7 or 8-lbs/cf of foam. The part, molded in one step, can range from being very soft to very rigid.

Rotolining and Co-Rotational Molding

LyondellBasell Microthene RL resins are produced by a proprietary process that incorporates chemically reac-tive, functional groups into the polymer structure. This chemical modification turns conventional polyolefins into Microthene RL adhesive resins that form strong bonds to a variety of substrates, such as metals, non-metals including other polymers.

Microthene RL resins provide resistance to a wide range of chemicals and are designed for applications requiring insulation or resistance to corrosion, abrasion or impact. Typical applications include linings, coating or tie-layers for pipes, drums, tanks or irregularly shaped parts. Microthene RL resins are normally shipped as powders for application methods such as rotational lining, co-rotational lining, powder spray and fluidized bed coating. Since Microthene RL resins bond to metal substrates, surface preparation affects adhesion in a manner similar to painted systems and the mold then becomes the finished part.

Table 4. Rotational molding resins: advantages and disadvantages

RESIN	ADVANTAGES	DISADVANTAGES
Polyethylene	Low cost Easy to mold	Lower impact strength than other resins
Polypropylene	Excellent ESCR High heat distortion temperature Autoclavable	Low impact strength at cold temperatures Higher cost than polyethylene
Microthene RL resins	Chemical bonding between resin and other material including metal	Higher cost than polyethylene
Polycarbonate	Clarity Toughness	Absorbs moisture Harder to mold than polyethylene
Nylon	Excellent impact strength High heat resistance	Expensive Harder to mold than polyethylene
Polyvinyl Chloride	Flexible Easily painted	Costs more than polyethylene Low stiffness
Polyester	Excellent impact strength in thin-walled applications	Expensive Harder to mold than polyethylene
Flame Retardant Polyolefin	V-0 rating	Lower impact strength
One-Step Foam	Foam-filled parts	Longer molding cycles

Molds for Rotational Molding

Inexpensive and Lightweight

Since very little pressure is exerted in the rotomolding process and no coring for cooling is necessary, rotational molds can be relatively simple. Because of this simplicity, the cost of a rotational mold is a fraction of that for a comparable injection or blow mold.

Two-piece molds are the industry standard, but three-piece molds are sometimes required to facilitate proper removal of the finished parts. Molds can be as simple as a round object or complex with undercuts, ribs and tapers.

Selection of rotational molds depends on the size, shape and surface finish of the piece to be molded, as well as the number of molds made for a particular piece. Molds should be as thin-walled and lightweight as possible.

Types of Molds

The most important property of a rotational mold is that its interior surface has to be completely non-porous. Cast aluminum molds are by far the most frequently used molds in the rotomolding industry. Most parts that are small- to medium-sized are molded with a cast aluminum mold.

Cast aluminum has good heat-transfer characteristics and is cost effective when several molds of the same shape are required. The only drawbacks to cast aluminum are it can be porous and easily damaged.

Sheet metal molds are normally used for larger parts. They are easy to fabricate and, in many cases, the sections of the mold need only be welded together. Sheet metal molds are cost effective when larger single-mold parts are required.

Other molds, such as electroformed nickel molds, yield an end product with very fine detail. Vapor-formed nickel molds, like electroformed molds, also yield very good detail but are more costly. CNC-machined molds and composite molds with jacketed heating elements are also used.

Table 5 lists the heat conductivity of metals used for making rotational molds.

Table 5. Heat conductivity of metals used in rotational molds

	BTU/hr, ft^2, °F, in.	g-cal/hr, cm^2, °C, cm
Steel	26	31
Aluminum	124	148
Copper	215	257

Flange-Mating Surfaces and Hinges

Any of the four types of flange-mating surfaces shown in Figure 5 are suitable. Each mold must be in two or more sections requiring good parting lines to have proper fit of the mold sections. Proper fit of the parting lines also yields little or no flash of the resin being used and provides correct formation of the finished part. The mating surfaces should be machined smooth for a good fit and the molds should be stress-relieved before the parting lines are matched.

The best parting line cannot function properly without a good clamping system. The most common clamping system for small-to-medium parts is the "C" vise clamp (Figure 6), which can be purchased in any hardware store. Spring-loaded clamps, welded onto the sections of the mold, are another popular option. As the molds get larger, nuts and threaded bolts are normally used. The threaded bolts are usually removed and installed with an air gun.

Figure 5. Parting Lines

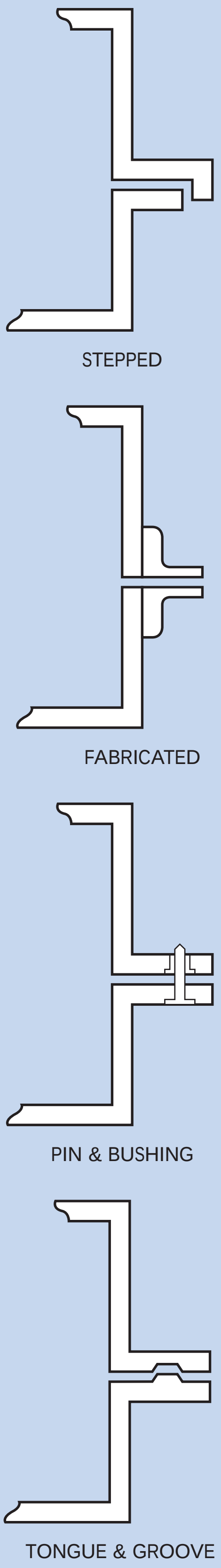
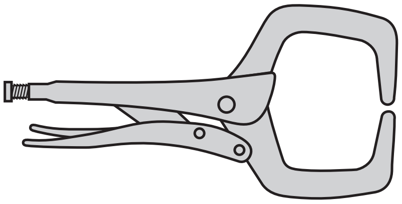


Figure 6. "C" clamp



Mold Mounting

Molds must be mounted on the spindle or arm of the rotational molding machine. Large sheet metal molds are easily mounted by bolts or simple clamping systems. With cast aluminum molds, a structure commonly known as a spider can be used to mount several small- to medium-sized molds on the same spindle or arm.

The spider consists of several arms or mounting legs to which each mold is attached, usually by bolts. In turn, the spider has one, central, mounting location that attaches to the machine spindle. This design allows two- or three-dozen cast molds to be mounted on one central structure.

The spider or a single large sheet metal mold may be removed easily with a forklift or crane. This is important because the rotomolding process typically is used for short production runs of a variety of parts.

Insulation Lids and Coverings

When openings are desired in rotationally molded pieces, insulating lids or inserts can be used. An insulating material is applied to an area of the mold to keep the powder from fusing at that point. Teflon® and silicon foams, among other materials, are commonly used.

If thin-walled sections are desired in a molded piece, they can also be obtained by covering a section of the mold with an insulting material that results in a small amount of powder sticking to the mold. The wall thickness can be controlled to a degree by changing the type or thickness of the insulating material.

Venting

Because of the inherent build-up of gas in the heating cycle of the rotational molding process, most rotational molds require a venting system.

A vent reduces flash and piece or mold distortion. It also prevents blowouts caused by pressure and permits the use of thinner-walled molds.

Depending on the size of the mold, vents can range from 1/8" to 2" inside diameter (I.D.). An industry rule of thumb is to use 1/2" I.D. tube for each cubic yard of part volume.

Since vents leave holes in the molded parts, correct placement is essential. The vents should be located in an area that may be cut out of the finished part or in an area where a patch does not reduce the aesthetic value of the end product. Figure 7 is a schematic presentation of a vented mold.

Vents must also be located to prevent water from entering the part while it is in the cooling cycle. Improper venting can cause many molding problems, such as water tracking on the inside of the end product.

Mold Release

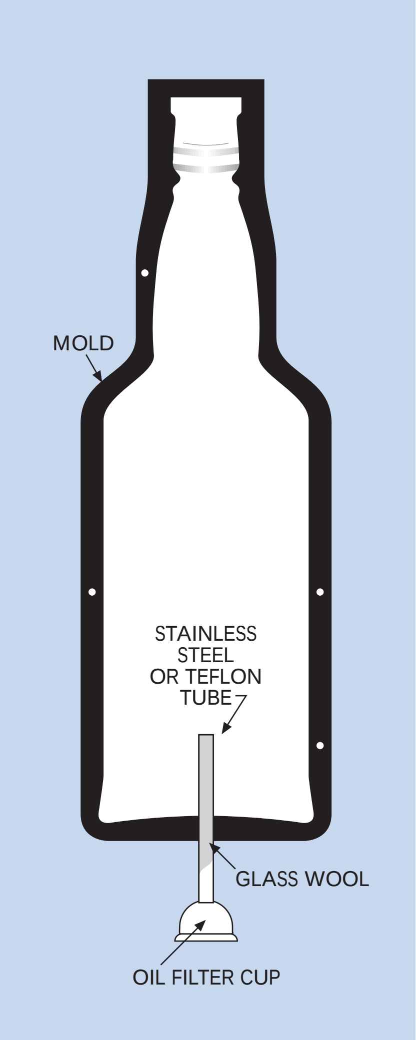
Since most rotational molds are designed with little or no draft angle, it is important to condition the molds with a release agent. Normally, molds are cleaned with a solvent and a lightly abrasive cloth to remove all foreign particles left on the surface during fabrication of the mold. After the mold is cleaned, a light coating of release agent is applied and baked-on to insure a good coating. With moderate use, the release agent does not adversely affect paint adhesion after flame treatment.

Molds that have been used with a plastic other than polyethylene may require special cleaning. Sand blasting with aluminum oxide or glass beads is the most effective way. Hand scrubbing with pumice and water works, but is very time consuming.

Environmental concerns have led to the development of water-based mold releases which are taking the place of solvent-based releases. Many molders are eliminating mold releases altogether by having molds coated with a fluoropolymer.

For a complete list of recommended mold-release agents and conditions of use, contact your LyondellBasell sales or technical service representative.

Figure 7. Schematic of vented rotational mold



Rotomolding Equipment

The equipment used in rotational molding is relatively simple but has many variations (Figure 13). The most common type of rotomolding machine is a multiple-spindle or carousel machine (Figure 14). Carousel machines are usually wheel-shaped. The spindles, each carrying a a group of molds or a single large mold, are mounted on a central hub and driven by variable motor drives. Most carousels have the freedom to rotate in a complete circle.

Figure 13. Schematic of a system used to obtain mold rotation in two perpendicular planes

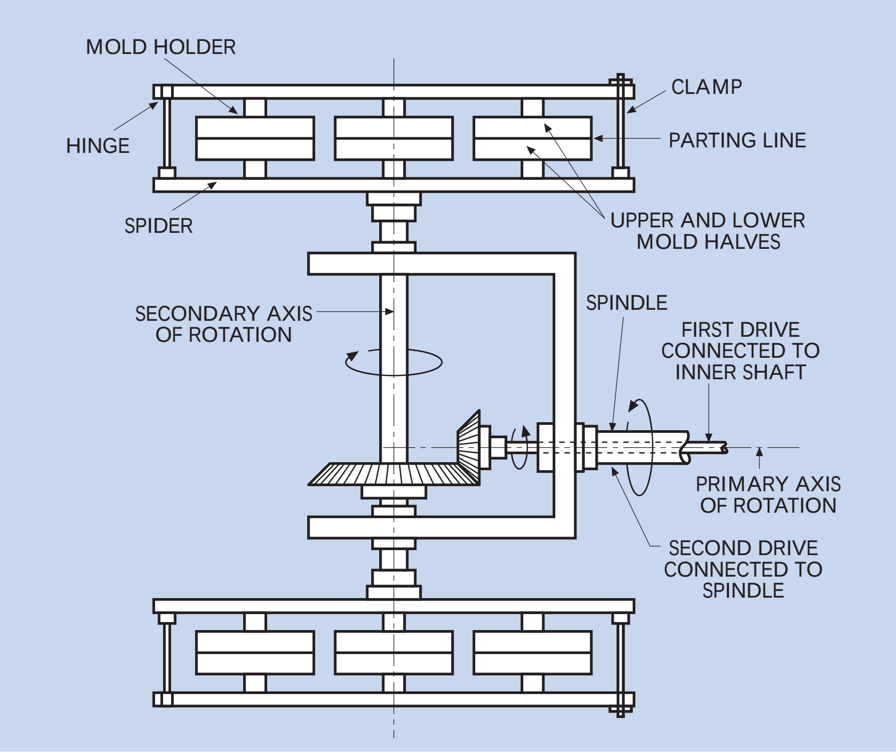
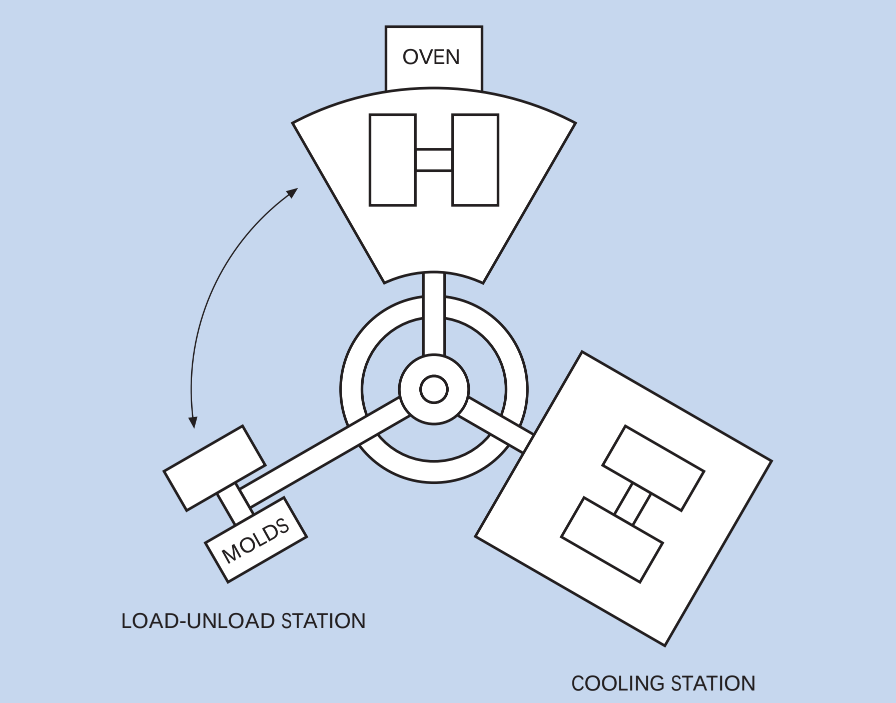


Figure 14. Carousel type machine



The carousel consists of a heating station or oven and a cooling station. In many cases, the carousel also is equipped with an enclosed chamber and a loading and unloading station.

The shuttle-type machine (Figure 15) is used most often to rotomold larger parts. A frame for holding one mold is mounted on a movable bed. Incorporated in the bed are the drive motors for turning the mold biaxially.

The bed is on a track that allows the mold and the bed to move into and out of the oven. After the heating cycle is complete, the mold is moved into a non-enclosed cooling station. A duplicate bed with a mold is then sent into the oven from the opposite end.

The clamshell (Figure 16) utilizes an enclosed oven that also serves as the cooling station. This machine uses only one arm and the heating, cooling and loading/unloading stations are all in the same location. Other types of equipment include "open-flame" and "rock-and-roll."

The newest type of rotomolding equipment is the Wytkin Composite Mold Technology (CMT), which utilizes a mold that is electrically heated and air cooled to produce the part (Figure 17).

Heating Stations

Most rotomolding ovens are fired by natural gas, using blowers to distribute heat throughout the chamber. Some ovens have the capability to be heated by oil or propane gas, but natural gas is the preferred method. Normal oven temperatures are 400° to 850°F (270° to 454°C). Ovens must be well insulated to minimize heat loss. Hot-air convection is the most commonly used heat source, although hot-liquid conduction and infrared radiation are also used.

Mold Cooling Stations

The cooling station may use a system to provide forced air for initial cooling and a water system to provide the necessary cooling of the molds and parts. Normally, a spray mist is used for even cooling. In many cases, however, only air-cooling is used. During the cooling process, the mold should be rotated. The cooling station may or may not be enclosed.

Instrumentation

Several advancements in instrumentation include computer simulation programs and data monitoring systems that help the rotational molder develop optimum cycle times and improve their molding efficiency.

Finishing Rotationally Molded Pieces

Pigment loadings in polyethylene powders for rotomolding should be kept to a minimum because high levels may cause reductions in the tensile, yield and impact strengths of the end product.

Figure 15. Shuttle-type machine

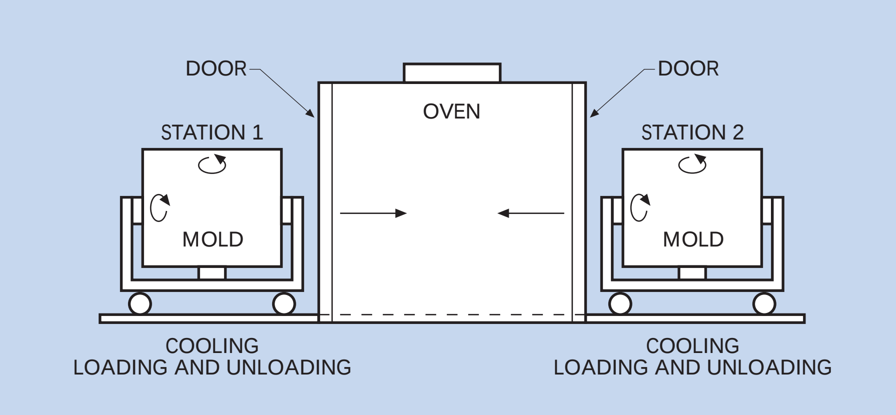
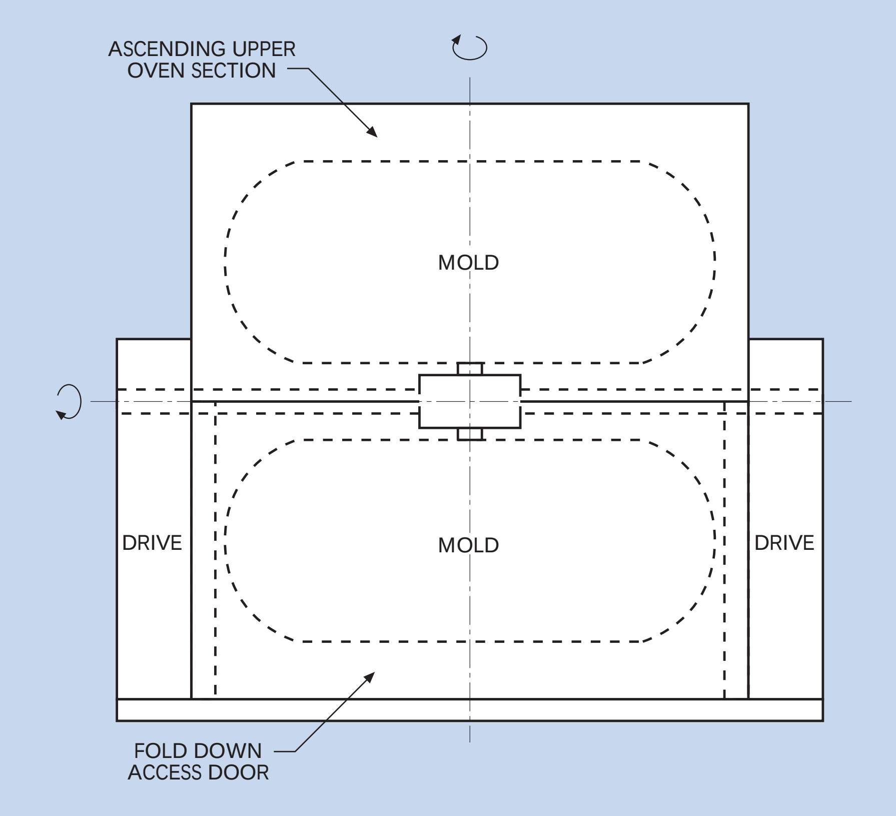


Figure 16. Clamshell mold



Any appropriate flame or electronic pre-treatment method can be used to promote ink and paint adhesion in printing and painting. Other than the desired end-product decoration, rotational molding requires practically no post-treatment. If there is flash along the mold parting line, it must be removed, although the creation of flash in rotational molding is usually negligible.

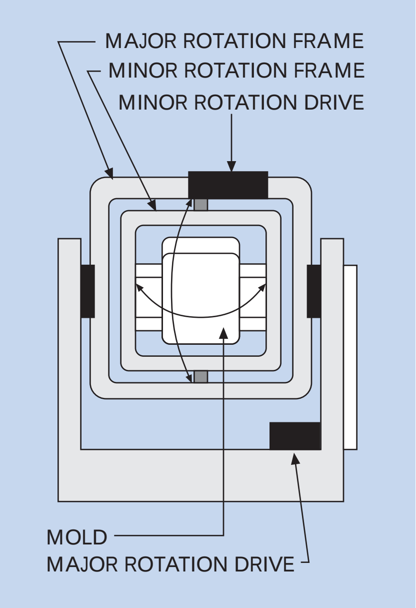
The addition of color to rotationally molded pieces is easily accomplished. The rotational molder may dry blend a color pigment into the natural powder. In this process proper dispersion is essential (one-quarter of one percent should be the maximum level used).

Another way to add color in the rotomolding process is by using a resin with compounded-in color. New developments in color technology allow parts to change color when under temperature. Granite and sandstone colors are also available.

Graphics can be molded-in or applied as a post-molding step.

Multi-axis routers allow for precision trimming of parts.

Figure 17. CMT technology



Troubleshooting Guide

As simple as it is, rotational molding with polyolefin powders is not completely problem-free. However, most problems encountered can be easily solved with a slight adjustment in operating procedures or by choosing a polyolefin powder with different properties.

What follows is a Troubleshooting Guide – an extensive listing of common problems and their most reliable remedies. If the suggested solutions fail to solve your particular problem, or if you have other problems, or if you need assistance in using Microthene polyolefin powders, contact your LyondellBasell polyethylene sales or technical service representative and tell them the required end-product properties and equipment available.

NOTE: The following guide covers use of basic polyethylene and, in many cases, polypropylene. For problems with LyondellBasell specialty resins, such as flame-retardant poly-olefin, one-step foam or rotolining resins, please contact your LyondellBasell technical service representative.

PROBLEM	PROBABLE CAUSES	SUGGESTED COURSE OF ACTION
Warped parts	Inadequate venting	1/2" (13mm) inside diameter (I.D.) vent per cubic yard (cubic meter) of mold volume is suggested for thin-walled parts
	Non-uniform cooling of the mold caused by resins pulling away from the mold wall	Rotate mold during cooling cycle Provide adequate venting and make sure vents are not clogged Use less mold release Avoid large, flat panels in part design if possible Reduce cooling rate during initial part of cooling cycle Increase the cooling medium temperature – air-cool, then water-cool Use all cool air Apply air pressure through spindle during cooling
	Non-uniform cooling caused by uneven part wall thickness	See suggested remedies outlined under the heading Problem: Uneven wall thickness of molded parts
	Non-uniform cooling caused by shielding panels	Mount mold to eliminate shielding Add baffles to direct heat
	Uneven cooling caused by clogged water nozzles	Check and clean nozzles on a periodic schedule
	Over-cured part. Degradation of the resin due to high and/or excessively long heating cycles	Decrease oven temperature or heating cycle, or purge part with inert gas (nitrogen)
	Highly underfused part. Some degree of underfusion is advisable, especially in the case of low melt index resins to prevent degradation.However, highly underfused parts can cause significant loss in impact strength	Increase oven temperature or total heating cycle Increase heat-transfer rate by using thinner mold walls, or make the mold from material with greater heat transfer coefficient, e.g., steel, aluminum, copper
	Improper coloring	Select pigment and pigment loading that does not affect strength Use precolored, compounded resin
	Resin type	Use proper resin having adequate melt index and molecular weight distribution for application
	Moisture on resin or pigment	Only use dry powder and/or pigment

PROBLEM	PROBABLE CAUSES	SUGGESTED COURSE OF ACTION
Parts stick in mold	Insufficient amount of release agent, or release agent has deteriorated with use	Reapply or use more release agent Old release agent may have to be removed and new one applied
	Ineffective mold release, or release agent does not withstand elevated temperatures	Use suitable mold release agent that is effective for resin and temperature used; apply according to supplier's instructions
	Interference during part removal	Locate mold parting line at undercut, or taper sides of mold
	Roughness and porosity of mold surface provide areas where resin may adhere	Refinish damaged mold surfaces (plug weld smooth)
	Presence of resin at parting line due to internal mold pressures which tend to force semi-molten resin through the parting line	Provide adequate venting: 1/2"(13mm) inside diameter (I.D.) vent per cubic yard (cubic meter) of mold volume is suggested for thin-walled parts
	Build up of degraded resin in the mold may be caused by burning of thin-walled sections	Clean the mold periodically
	Shrinkage onto large deep inserted areas	Provide adequate taper Use very effective mold release on insert area Remove part while warm Make adequate provision for applying force to separate mold halves
	Low shrinkage value for resin	Use a higher density resin
	All of the above	Use Teflon coating on mold and/or parting line
Poor impact resistance	Resin selection not correct	Use a lower density or lower melt index resin
	Density increase during slow cooling	Increase the cooling rate to maintain lower density
	Part design not appropriate	Review and alter mold design if necessary, eliminating sharp corners and narrow passages
	Insufficient fusion of resin	Increase temperature or heat time
	Improper coloring	Select pigment and pigment loading that does not affect impact Use precolored compounds
	Over-cured resin	Decrease oven temperature or time
Powder bridging or not filling narrow passages in mold	Mold design incorrect	Modify mold by increasing width-to-depth ratio across the mold opening Design corners or mold with more generous radii. Avoid ribs with width less than four time wall thickness
	Poor pourability (dry flow) of powder	Make sure powder has acceptable pourability and bulk density
	Powder does not melt or flow properly	Use a finer mesh powder or a resin with a higher melt index
	Cold spots on mold	Avoid any shielded mold areas Check for mold wall thickness uniformity Add airflow amplifiers
	Improper mold rotation speed	Use correct ratio and location

PROBLEM	PROBABLE CAUSES	SUGGESTED COURSE OF ACTION
Long-term part failure	Part under- or over-cured during molding	Obtain proper cure
	Photodegradation of part caused by ultraviolet light from sun or internal lighting (fluorescent)	Use a UV-stabilized resin in application Add suitable UV stabilizer and/or pigment. A fine, well-dispersed carbon black provides the best protection
	Stress cracking due to multiaxial stresses in part; may have been accelerated by chemical environment and temperature	Use stress crack resistant polyethylene grade Do not store an environmental stress crack solution in a container molded from a poor environmental stress crack grade of polyethylene for a long period of time ar at elevated temperatures Modify design around any area containing inserts Examine part under field conditions to determine adequacy of design and stress concentration points
	Inadequate resin additive system	Antioxidant type and level of inclusion may be insufficient Reduce level of internal mold release if used
	Color changes due to oxidation	Reduce oven residence times
	Improper colorants or blending	Use colorant that disperses well in base resin Compound resin and pigment for a homogenous mixture before grinding
Uneven wall thickness of molded parts	Improper mold rotation	Vary ratio and speed of the rotating mold to obtain even coverage and adequate number of powder trackings
	Mold shielded	Mount mold to eliminate shielding
	Uneven mold wall thickness	Use care in designing molds to prevent excessive variation in mold wall thickness (thin spots attract more resin)
	Inadequate powder properties. Low bulk density, no powder pourability, large amount of fluff, particles have many tails which entangle into clumps during molding	Obtain an acceptable powder
	Buffeting of air flow in deep dished areas	Avoid deep dished areas when possible Reduce thickness of mold in dished areas Open handles so that air can flow through kiss-off in mold Use airflow amplifiers
	Surface moisture from cryogenic grinding (polypropylene only)	Dry resin before molding
	Too fast fusion (polypropylene only)	Lengthen heating time and lower oven temperature
Blow holes through part or ringworm effect under outer part wall surface, other than parting line	Porosity in cast aluminum mold	Obtain better quality castings Drill through void and drive in pin or weld from outside Relieve from outside by drilling into void from side Remove parts from molds while mold is quite warm to touch. This helps drive moisture out of pores
	Pores or holes in welds	Use proper welding rod and procedure. Weld inside surface first to get good penetration

PROBLEM	PROBABLE CAUSES	SUGGESTED COURSE OF ACTION
Bubbles on the parting line	During the first stages of cooling, there will be a rush of air into the part to fill the resultant partial vacuum. If there is inadequate venting, air will enter molten resin at the parting line and become trapped as the part wall solidifies	Vent the mold to atmosphere pressure Relocate vent to middle of mold Use appropriate material in vent Use Teflon vent tube Vent too small
	Poor mold parting line	Re-mate parting line and adjust mold clamp pressure evenly Clean mold flange to prevent gapping and apply new mold release on flange
Excessive flashing at mold parting line	Internal mold pressure during heating cycle tends to force semi-molten resin out through the parting line	Provide adequate venting and make sure vents are not clogged Re-mate mold parting line and adjust mold clamp pressure evenly Clean mold flange to prevent gaping and apply new mold release on flange Reduce internal most air pressure that is used Use lower melt index resin
Long cycles	Heat-transfer rate not adequate to melt all the resin, excessively thick mold	Increase heat-transfer rate by using thinner mold walls, or make mold from material with greater heat-transfer coefficient, e.g., steel, aluminum, copper
	Heating not efficient	Increase air velocity around mold during heating cycle
	Low oven temperature	Increase oven temperature Recalibrate instruments as they may be reading high
	Resin powder too coarse	Use a finer mesh powder
	Poor flow	Use a higher melt index resin
	Extended cooling	Reduce air-water cooling time ratio
Discoloration of inside surface of part	Degradation of resin due to high temperature and/or excessively long heating cycle	Decrease oven temperature or heating cycle, or purge part with inert gas (nitrogen) Use resin containing the proper amount and type of antioxidant Check pigment for heat stability
	Uneven heat transfer	Mount mold to avoid hot spots
Highly underfused parts, with many small bubbles in wall or rough, powdery inside surface	Oven temperature not high enough to close-up bubbles in the walls of the part	Increase oven temperature or total heating cycle
	Heat transfer rate not adequate to melt all the resin	Increase heat-transfer rate by using thinner mold walls, or make mold from material with greater heat-transfer coefficient, e.g., steel, aluminum, copper
	Resin powder too coarse	Use a finer mesh powder
	Moisture in mold	Reduce moisture in mold by running with warm molds and dry mold before charging with powder
	Surface moisture from cryogenic grinding (polypropylene only)	Dry resin before molding

PROBLEM	PROBABLE CAUSES	SUGGESTED COURSE OF ACTION
Speckled color and lumps of color in dry blended colors	Insufficient blending	Break up agglomerates of pigment before blending Use high intensity mixer. If unable to achieve a desirable color balance, use a colored compound Check for contamination
Blow holes through part around inserts	Poor fit on inserts allowing moisture or vapors to be trapped around insert and expand, blowing a hole in the part	Refit inserts and relieve to allow trapped gases to escape to the outside of the mold Precoat insert with powder
	Bridging of resin because of close dimensions	Change insert dimensions or location to allow powder to flow without bridging
Poor part stiffness	Part wall too thin	Add more powder to the initial charge
	Resin selection not correct	Use resin of higher density
	Part design not appropriate	Review and alter mold design if necessary
	Underfused parts	Increase oven temperature or total heating cycle Increase heat-transfer rate by using thinner mold walls, or make mold from material with greater heat-transfer coefficient, e.g., steel, aluminum, copper
Lightning effect in colored parts	Moisture in pigment	Dry resin before molding
	Static buildup	Apply a small amount of antistat or mineral oil to the resin
	Pigment not ground properly	Use 100 mesh pigment or pulverize pigment Use precompounded colors

Industry associations and information sources

The Association of Rotational Molders (ARM), located near Chicago, Illinois, is an international organization representing the rotomolding industry.

ARM has compiled an extensive library of literature on rotational molding. It has also published a design manual, the first of its kind for the industry.

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The Rotomolding Process

There are six steps in the rotomolding process:

1 The mold or cavity is filled with a predetermined amount of polyethylene powder, such as LyondellBasell Microthene powders. This is called “charging the mold.”

Weighing the polyolefin powder

2 The mold halves are secured together by a series of bolts or clamps. For totally enclosed pieces, the entire mold is made of heat-conductive metal. When one or both ends of the piece are open, heat-insulating covers are used to close the mold.

Filling the mold

3 The charged mold is placed in an oven where it is heated and simultaneously rotated around two axes in planes at right angles to each other.

Programming the movement of the arm

4 During the heating/rotation cycle the resin melts, fuses and then takes on the shape of the mold being used to form the hollow object.

5 When all the powder has fused into a homogenous layer on the walls of the mold cavity, a combination of air and water is used in a cooling chamber to cool the mold slowly. This helps maintain the part’s dimensional stability.

The mold moves from the oven to the cooling chamber

Removing the finished item

6 The molds are removed from the cooling chamber, opened and the finished parts removed. The mold is then readied for the next cycle.

Before the molds are recharged and steps one through six repeated, it is important to be sure no moisture is on the inside of the mold.

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