

Rotational Molding: The Basics for Designers

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Rotational molding is a method for manufacturing hollow plastic products. It is best known for the manufacture of tanks, but designers all over the world now realize that it can be used to make many different types of plastic parts. Some of the sectors that it services include: medical products, consumer products, agricultural and garden equipment, automotive and transportation components, toys, leisure cart and sporting equipment, furniture, materials handling articles, and highly

aesthetic point-of-sale products.

The rotational molding industry is an exciting and innovative part of the plastics manufacturing sector. In recent years, many significant technical advances have been made, and new types of machines, molds, and materials are becoming available. Important new market sectors are opening up as rotational molders are able to deliver high-quality, high performance parts at competitive prices. In the portfolio of manufacturing methods available to designers, rotational molding can now take its rightful place alongside the other major processes, such as blow molding,

thermoforming, and injection molding.

This article provides an overview of the key features of rotational molding. It describes the basic nature of the process and provides information on some of the things that must be taken into account when designing rotomolded

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plastic parts. Detailed design guides for rotational molding are cited at the end of the article.

The Process

The principle of rotational molding of plastics is relatively straightforward. Indeed, the simplicity of the process is a key to its success because it allows the molder to exercise close control over part dimensions and properties. Basically, rotational molding consists on introducing a known amount of plastic in powder, granular, or liquid form into a hollow, shell-like mold. The mold is heated and simultaneously rotated about two axes so that the plastic enclosed in the mold adheres to, and forms a layer against the mold surface. The mold rotation continues during the cooling phase so that the plastic retains the desired shape as it solidifies. When

the plastic is sufficiently rigid, the mold rotation is stopped to allow the removal of the plastic product from the mold. The process is distinguished from spin-casting or centrifugal casting by its relatively low rotational speeds, typically 4 - 20 revs/min.

The basic steps of (a) mold charging, (b) mold heating, (c) mold cooling, and (d) part ejection are shown in figure 1. This diagram is for illustration purposes only. In reality, there are many types of commercial and custom-made machines for manufacturing plastic parts using the rotational molding principle. Most large commercial machines are of a «carousel» design. In these machines, the mold or molds are mounted on an arm that imparts the biaxial rotational to the molds and carries them sequentially into the heating zone, the cooling zone, and finally into the de-molding/charging area. Three arms are often used so that heating, cooling, and servicing can be carried out simultaneously on three different sets of molds. In some cases the arms are fixed together at 120° spacing. In other machine designs, the arms can be moved independently of each other so that, for example, the molds being can be moved out of the oven if the homogeneous melt coating has been formed on the mold wall before the cooling has been completed on the preceding arm.

In the other main type of machine design, the molds go through a «rock and roll» motion - full 360° rotation about one axis and a rocking motion about a perpendicular axis. In both types of machines there are many permutations of the sequencing of heating, cooling, and mold servicing, as well as many combinations of single and multiple ovens and cooling areas. Heating is usually achieved using a hot gas oven, but open flame burners, as well as infra-red, conductive, inductive, and dielectric heating methods are also used.

Characteristic Features of Rotational Molding

Rotational molding is an atmospheric pressure process that produces nearly stress-free parts. The fact that there is very little stress on the melt as it is shaped is a major advantage that rotational molding has over all the other manufacturing methods for plastic parts. Also, as there are no forces on the plastic melt during forming, molds can have thin walls and are relatively inexpensive to fabricate. Delivery times for new molds can be significantly less than for injection molding or blow molding.

In some cases, several mold





Table 1: Comparison of blow molding, thermoforming, and rotational molding (Adapted Thorne, J.L., *Plastics Engineering*, 54, 10, (1998))



Table 2: Examples of typical types of rotationally molded parts.

types, and different plastic materials, can be produced simultaneously. With proper mold design, complex parts that are difficult or impossible to mold by any other method, such as double-walled containers, can be rotationally molded. With correct process control, the wall thickness of rotationally molded parts is quite uniform, unlike structural blow molding or twin-sheet thermoforming. And unlike these competitive processes, rotational molding has no pinch-off seams or weld lines that must be trimmed or finished after molding.

The main attractions of rotational molding are:

- A hollow part can be made in one piece with no weld lines or joints
- The molded part is essentially stress-free
- The molds are relatively inexpensive
- The lead time of the manufacture of a mold is relatively short
- Wall thickness can be quite uniform (compared with other free surface molding methods such as blow molding)
- Wall thickness distribution can be altered without modifying the mold
- Short production runs can be economically viable
- There is no material waste in the at the full charge of plastic is normally consumed in making the part
- It is possible to make multi-layer parts, including foamed parts
- Different types of products can be molded together on the one machine
- Inserts are relatively easy to mold in
- High quality graphics can be molded in.

The main limitations of rotational molding are:

- The manufacturing times are long
- The choice of molding material is not as great as with other molding methods
- The material costs are relatively high due to the need for special additive packages and the fact that the material must be ground to a

fine powder

- Some geometrical features (such as ribs) are difficult to mold

Table 1 compares the characteristics of the different processes that can be used to make hollow plastic products.

Application Areas

Nowadays rotationally molded parts are used in practically every market sector where plastic parts are found. This includes high technology sectors, such as the aircraft industry. The process is best suited for the manufacture of one-piece hollow parts or double-wall open containers.

Secondary operations can be used to split moldings or cut out panels so that most types of single-wall open containers and products can be created. Areas that are to be cut out of a molding can be shielded from the heat during molding so that plastic does not adhere to the mold in these areas, and so there is very little material waste as a result of the cutting/trimming operation.

Table 2 gives examples of typical types of rotationally

molded parts. It may be seen that the variety of products is impressive and although polyethylene is the primary material in most cases, high performance, and structural parts are possible through the strategic utilization of unique features such as internal «kiss-off» points between the double walls of the hollow part.

Some examples of rotationally molded parts are shown in figures 2(a-h). A key point is that they are all complex 3-dimensional shapes, and they are all made in one piece. Foaming is also very common in rotationally molded parts to provide thermal insulation or high stiffness at minimum weight.

Materials

Nearly all commercial products manufactured by rotational molding are made from thermoplastics, although thermosetting materials can also be used. The polyolefins (mainly polyethylenes) dominate the market for rotationally molded parts. There are several reasons

why this situation has arisen. One is that this material is readily converted from granules to the powder form needed for rotational molding. Another is that polyethylene remains more stable than most plastics during the relatively long heating period.

Currently, polyethylene, in its many forms, represents about 85% to 90% of all polymers that are rotationally molded. PVC plastisols are quite widely used and polycarbonate nylon, polypropylene, unsaturated polyesters, ABS, acrylics, cellulose, epoxies, fluorocarbons, phenolics, polybutylenes, polystyrenes, polyurethanes, and silicones make up the rest. The relative proportions of the usage of these various materials are shown in figure 3. High performance materials such as fiber-reinforced nylon and PEEK show potential to be used in this technology but represent a very small fraction of the industry output.

Molds

The molds used in rotational molding are shell-like constructions. They are normally made in two halves from metal, although complex parts may require molds to separate into three or more pieces.

The molds are held closed at the parting line



by clamps. The mold almost always has a vent tube ("breather") to ensure equalization of pressure between the inside of the molded part and the external environment. The positioning of the vent tube depends on the nature of the plastic part - for example, the fill port of a tank is a convenient place to locate the vent.

The most common mold materials are cast aluminum or fabricated sheet steel. The latter is favored for large articles such as tanks, whereas casting is used for smaller parts that contain complex details, or where several identical molds are required. Electroformed or vapor-formed nickel plate molds are also used, particularly for PVC parts. The use of CNC machined molds is becoming common, and this is resulting in exciting improvements in mold quality, particularly at the parting line. In recent years there have been other materials, such as fiber reinforced epoxy, used for molds.

Molds undergo high thermal stresses as they are regularly cycled from room temperature to over 300°C (over 600°F), and finite element analysis of CNC machined molds ensures that high performance can be maintained over long periods of time. The desirability of having small positive pressure inside the

mod can also be realized more easily in computer designed molds. Automation of mold opening and mold filling is also helping to reduce cycle times and improve consistency in the molded part. Some recent molding "machines" are in essence simply a mold, with direct heating through electrical conduction or an oil jacket around the mold. Precise control of the rotation of the mold makes it easier for automated mold filling, and part extraction

Design Guidelines

The nature of rotational molding creates some special effects not seen in other molding processes for plastics. Outside corners of molded parts are usually thicker than the general wall thickness because the plastic powder gathers in the corner of the mold. Conversely, inside corners are usually thinner because the plastic powder falls away from the mold in these areas. The generally recommended radii for inside and outside corners are illustrated in figure 4. The general rule of thumb for inside and outside corners is that larger radii will give more uniform wall thickness.

Rotational molding, like blow molding and thermoforming, is a free surface

method. Wall thickness variations will occur in rotational molding, but the molder can exercise close control over wall thickness by altering the speed ratios about the major and minor axes. In addition, some areas of the mold can be shielded to reduce material build-up, or extra heat can be directed to areas where more thickness is required.

The shrinkage in polyethylene is large, typically 3-4%, but this can be allowed for. Dimensional tolerances of 1-2% can be achieved in rotational molding. A flatness tolerance of 2-5% is usually the best that can be achieved due to the warpage that tends to occur as a result of the one-sided cooling in rotational molding. Where possible, large flat areas should be avoided in a molded part, and the use of curved surfaces is highly recommended to conceal warpage effects.

Threads, both internal and external, can be molded, although coarser thread profiles are preferred. Commercial "flow enhancers" can be sprayed on to the mold in areas such as thread profiles and these improve the reproduction of the mold details considerably. Metal inserts are also very common in rotationally molded parts. The relatively large shrinkage of polyethylene ensures that inserts are tightly

molding



gripped during molding, but it must be recognized that the resulting restriction of the shrinkage will introduce residual stress. The nett effect is that, as is often the case with polyethylene, care must be taken with the use of inserts if there is the possibility that the molded part is exposed to a stress cracking agent. Conventional ribs are difficult to create by rotational molding because the plastic powder does not flow easily into the recess needed to create the rib. Instead, the same type of stiffening effect can be created using corrugations as shown in figure 5. The recommended depth of the corrugations is about four times the material thickness and the width should be about five times the material thickness. This is to ensure a good balance of axial and transverse stiffness. Special stiffening features called "kiss-offs" are very effective in rotational molding (see figure 6). These are created in double wall parts by conical features in the mold that cause the two walls of the part to be bonded together. The resulting molding is very stiff and in some cases, such as in pallets, foaming is added to provide excellent stiffness to weight ratio.

Draft Angles are usually not necessary in female parts of the mold because the plastic will shrink away from the mold. However, in male parts of a mold where there is a tendency for the plastic to shrink on to the mold, draft angles of 1-20 are usually sufficient. These are illustrated in figure 7. If the mold is textured, an extra 1-20 are usually sufficient. These are illustrated in figure 7. If the mold is textured, an extra 10 taper should be allowed. These values of draft angle are for polyethylene. An extra degree should be allowed for stiffer materials such as polypropylene and nylon. Very stiff materials, such as polycarbonate, will require a further 20 in all cases.

Some Undercuts are permissible in rotational molding where the material

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shrinkage or flexibility will allow the material to pull away from the mold. The designer will need to determine what is possible based on knowledge of the shrinkage. Generous draft angles on external undercuts will help the material to pull away from the mold. Internal undercuts are not permissible since the shrinkage of the material will prevent ejection of the part. These effects are shown in figure 8. Note that the undercuts drawn here are for illustration purposes only. As described above, rib-like features of the type shown are difficult to produce in rotational molding and in practice are likely to be designed as more elongated corrugations. Holes cannot be molded-in using rotational molding; they must be machined afterwards using normal types of cutting tools. During molding, it is common to shield the areas to be cut out so as to avoid material wastage. Although polyethylene is difficult to paint, sophisticated decorating methods have been developed for rotationally molded parts. Several techniques are available. In one case, special transfers can be applied to the mold, and these are picked up by the polyethylene during the normal molding operation. In other cases, the transfer can be applied after molding. Both methods are extremely effective at providing excellent graphics on rotomolded parts as shown in figures 2 (a) and (e).

Concluding Remarks

Rotational molding is an extremely versatile manufacturing method for plastic parts. It can provide high performance parts in demanding market sectors, because it is capable of producing stress-free parts, available with short lead times and attractive economics. The rotational molding industry is a dynamic sector with molders and suppliers who are innovative, and enjoy new challenges. The following websites will give the

reader further details of the process and provide further examples of molded parts:

- ARM International
- ARMO
- ARMA
- AISR
- SARD
- Etc

Bibliography

Those wishing to obtain more detailed information on the rotational molding of plastics are referred to the following sources of information [1-8]:

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