BASIC PRINCIPLES OF ROTATIONAL MOLDING

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*Trademark - Acetal Copolymer

HISTORY OF ROTATIONAL MOLDING

It is rather surprising to note that the first patent dealing with the rotational molding process was applied for back in 1855 by an Englishman named Peters. According to a patent search published by L.R. Whittington in 1961, Peters' invention described a rotating mechanism employing two axes disposed at 90° and connected by a pair of bevel gears - the exact arrangement found in most commercial machines today. Further investigation of Peters' patent reveals that a hollow mold (of two or more parts) is used, metal or other substance in a fluid or semi-fluid state is added, biaxial rotation is employed to distribute the material evenly around the mold cavity, and a vent pipe to permit gases and air to escape from the cavity is discussed. External cooling of the mold with water or other cooling matter is also mentioned.

Another patent, issued to Voelke in 1905, concerns the use of molten paraffin wax in a non-porous mold, and the transition from a fluid to a solid by cooling while the mold is rotated about two axes.

In 1910, an apparatus patented by Baker and Perks involved the rotational casting of chocolate eggs.

The presently popular 4 to 1 ratio between speeds of the primary and secondary axes was first mentioned in a 1920 patent of Powell's. He likewise stressed the importance of avoiding centrifugal force by slowing the rotation speed.

Vinyl chloride polymers were first mentioned in a rotational casting process patent issued to Clewell and Fields in 1941. This patent, except for only minor differences, encompasses all elements of rotationally casting vinyl plastisols.

The period from the mid 1940's to the late 1950's saw the true emergence of vinyl plastisol molding with many processing patents filed. During this period, refinements in the rotational molding equipment and handling techniques were particularly emphasized.

It was in 1958 that U.S. Industrial Chemicals Company introduced polyethylene powders in the United States. The first material was in the form of precipitated powder which was followed two years later by a mechanically ground powder. This powder, which was to become the more popular, resulted in a polyethylene form that was competitive in price with vinyl plastisols, and with injection and blow molded items.

THE UNIQUENESS OF ROTATIONAL MOLDING

Some of the basic differences that characterize rotational molding from the other molding processes include: a) the use of liquid plastisols or thermoplastic powders instead of pellets; b) the melting of the molding material inside the mold instead of forcing the molten material, under pressure, into the mold; c) the use of biaxial rotation of the molds; and, d) the use of molds that are comparatively inexpensive because of their simplicity due to the lack of pressure in processing and lack of coring for water cooling.

The advantages of rotational molding, when compared to the other molding processes, are listed in Table 1.

CRITERIA FOR SELECTING ROTATIONAL MOLDING

The decision as to which molding technique is best suited for a given application involves a number of factors. Most important among these are: 1) form and design of the part, 2) size of the part, 3) weight of the part, and 4) anticipated length of the molding run.

Rotational molding can be used to make practically any shape, providing it is hollow. However, this need not be too limiting when considering the many ways in which a hollow design can be utilized to make a seemingly solid item, such as sun visors and arm rests.

The unique design freedom that rotational molding offers is one of the most significant differences from the other molding processes. Unlike restrictions which exist in blow and injection molds where draft angle (taper) is so critical, rotational molds can be designed with essentially no draft. This when the parting line lies in more than one plane. Sheet metal molds are used for low cost large molds of fairly simple design. Electroformed copper and copper-nickel molds are the most expensive but offer the advantage of a very smooth finish.

It is essential that molds used are non-porous. During cooling water spray can be trapped in mold pores. During the next heating cycle this water will generate steam which can affect part surface.

Mold Clamping. Due to the constant thermal cycling of the rotocasting process, molds tend to warp with use if proper care is not exercised. Clamping force should be kept to a minimum and should not be much more than that needed to stop molten material from exuding or flashing at the parting line during heating.

Molds and spiders (devices for holding molds) should be stress relieved before final matching of parting lines, especially for production molds.

Clamping devices vary from use of C-clamps and vise grips to spiders with built-in clamping devices.

PART DESIGN

The rotocasting process gives wide flexibility in the shape or size of parts that can be produced. As long as the mold configuration allows contact between the material and the mold surface, the mold shape can be reproduced. Mold size must be contained and rotated within the limitations of the heating and cooling chambers. Generally, wall thickness can be controlled, within ±5%. Parts using various resins have been molded with walls as low as .015 in. or as thick as .500 in. Little or no draft angle is necessary for release, as the part is not formed under high pressure and will tend naturally to shrink from the mold.

There are some design limitations in the process:

a. Varying wall thicknesses cannot be easily cast in the same piece - varying rotational speeds (and ratio) and insulating mold sections accomplish this to a degree, but wall thickness cannot vary sharply in a short distance. There are three methods of varying wall thickness:

1. At sections where a thicker wall is desired, the mold wall is cast thinner; therefore, heat is conducted more rapidly in this section. This practice is more art than science and a number of experiments must be run to determine mold wall thickness variations. Probably the best method would be to start with a mold of the same cross section and machine the outer surface of the mold until the desired variation in wall thickness is obtained in the finished part.

2. Sections of the mold where a thicker wall is desired are painted a dark color for absorption of heat. Where a thinner wall is desired a light color paint is used for reflection of heat.

3. Semi-hollow parts such as open end containers and housings can be molded by insulating the top of the mold with asbestos sheet or board. This will eliminate or significantly reduce material deposition in this area.

b. Sharp threads are impractical since material will tend to bridge in a confined area.

c. As a general rule to prevent bridging in ribs or baffle-like shapes, the distance between interior walls should be four times the wall thickness.

d. As in injection molding, wall thickness transitions should be as gradual as possible to prevent built-in stress due to differential cooling.

e. Molds must be designed using proper shrinkage. Since only low pressures are used in rotocasting, shrinkage values for various resins might be somewhat greater than for injection molded parts. Shrinkage is a function of process conditions, primarily cooling rate and wall thickness.

SUMMARY

As mentioned earlier this process is far from mature. More automated machinery is needed especially in the unloading - loading step to reduce the overall cycle for continuous machines. Reduction of heating time is fine until the rate limiting step in production becomes unloading and loading.

Better control of the heating cycle is needed as most machines are instrumented to read oven temperature at only one point in the oven. Measurement of mold and material temperatures will be needed in the future for close control and minimization of the heating cycle.

Resins to be used in the process might have to be tailored for thermal stability in order to produce thick walled parts. This necessitates extensive development from material suppliers.

Reference

1. "The Production of Rotationally Moulded Hollow by the Activated Anionic Polymerization of Lactams," Translation from Kunstoffe, 58, June 1968, p. 6.

PART AND MOLD DESIGN

Richard R. McCort

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For those of us who have been the first contact for people interested in investigating the rotational molding process the most discouraging thing that can happen is to be greeted with the phrase "Can you make me a part like this?" and then have our client present us with a metal part. Yes we can duplicate the part but we can do much more.

For several years the machinery manufacturers and mold suppliers have been endeavoring to spread the word to those responsible for design that rotational molding is not only an economical way to manufacture a given product but that it also has many unique advantages that will give the designer new found freedoms. Before we discuss part design it is first necessary to familiarize ourselves with the various types of molds available and the advantages of each.

The four basic types of tooling are the cast aluminum mold, electroformed nickel mold, the fabricated or sheet mold, a combination of cast and fabricated components and machined molds.

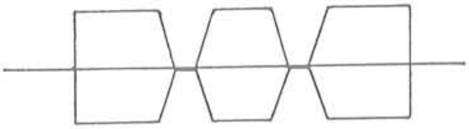
Cast aluminum molds are used the most extensively where a group of cavities are mounted on a common frame or spider and parted simultaneously and when additional strength is desired. Electroformed molds are widely used for flexible products where no parting line is used. The fabricated mold is probably the most economical and is used for angular and cylindrical shapes and for extremely large products. Papers on each of these processes will be presented later in the program so we will not dwell further on the merits of the particular methods.

The foremost advantage of the rotational molding process is the freedom allowed to the designer. There is practically no limitation to the configuration that can be molded. One and two piece molds are the most widely used but it is not uncommon to have multiple piece molds particularly in cast aluminum.

When designing the part and planning the mold construction it is very important to give consideration to the type of plastic material that is to be used. Some materials are flexible enough to permit the inclusion of some undercuts in the mold. Other materials will shrink sufficiently to facilitate easy removal but there are those materials that will not tolerate any undercuts and in these instances the mold must be designed with sufficient drafts to release the finished part. For those materials that are not pliable or that do not shrink we advocate the use of a one or two degree draft.

The volume of production anticipated is very important in planning the mold design. The fact that the parting line can travel on several planes makes it possible to design the great majority of molds in just two pieces. However, when it is necessary to have a third piece to a mold such as the belly section in a hobby horse or hexagonal furniture parts the design of the cavity is still relatively simple. The tongue and groove molds or the new parting line which we have developed at Roto Mold and Die makes it easy to lock the multiple piece mold together and when working with the single mold in prototype work there are very few problems. However, if the part is destined for mass production then the mounting of several cavities on one arm becomes quite complicated. If the value of the end product justifies the means then there is no limit to the complexity of loading and unloading that can be tolerated. If the end product is relatively inexpensive then it is mandatory that ease of servicing the molds should be the foremost thought.

The large flat surface is the most difficult section to rotationally mold. The proper application of mold releases and the use of air pressure within the mold during the cooling cycle can do much to alleviate this problem but when designing the part it can eliminate much frustration if some type of design is worked into the large panels. Contoured ribs or perhaps an embossed design will help tremendously in eliminating oil canning. Since the panel has a tendency to suck in it can be a definite advantage to concave the mold slightly. If the part is functional rather than decorative it is often practical to use "kiss-offs." That is to have a hollow insert on each half of the cavity so that a support is formed from one wall to the other.



CROSS SECTION SHOWING 'KISS-OFFS'

The double wall construction is one of the unique advantages of our process. Such products as ice chests, missile containers and other contoured carrying cases are being rotationally molded with the two walls as close as a ½" apart.

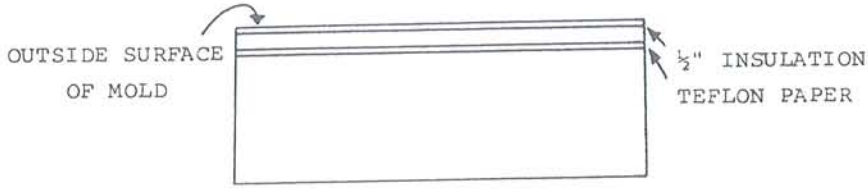
When planning on using the double wall it should be kept in mind that the inside wall is formed on a core and that if the material being used has a very great shrinkage factor the material will be shrinking against the core so the core must be well lubricated and the part must be pulled at the right temperature. The "kiss-offs" that I mentioned previously must be considered in the same manner.

When considering the double wall it is necessary to insure that your heating media can penetrate the furthest limits of the core. When using a liquid heat the mold is generally thicker (½") than the convection hot air mold (¼" to 5/16"). It is advocated by some people in the industry that the outside mold should be thick so that it will take the heat longer to penetrate this section while the inside of the core should be as thin as possible so that the material will fuse equally to all surfaces. It is our opinion that the surest way to obtain a uniform wall thickness of the finished part is to baffle that part of the mold that is open to the heat and this will allow the inner core to heat up at the same rate as the exposed surface.

The designer of the rotationally molded part should be aware of the various type mold surfaces which are available to him. As in the other plastic processes the more highly polished the mold surface the glossier the finished part. All of the molds mentioned are capable of being highly polished but the machined molds and the electroformed molds lend themselves to the very high surface finish the best.

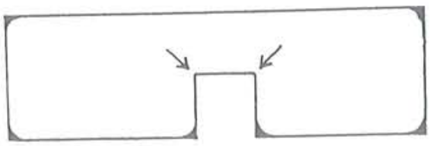
The look and feel of some of the materials can be greatly improved by incorporating a grain or textured surface in the mold. If at the extreme opposite of the highly polished surface a mat finish is desired the mold surface may be sand, lime or walnut shell blasted. Blasting will of course take away some of the definition on a grained or textured surface.

In many instances it is desirable to void out a section. This can be done by use of insulation. For small holes Teflon plugs are used. The larger voids may be accomplished by using about a ½" of insulating material on the part of the mold which is to be blanked out. An additional advantage may be had by covering the insulation with Teflon paper. The insulation retards the heat and the non-adhering qualities of the Teflon combine to do a very thorough job. It is also practical to build a knife edge into the mold along the lines of the knock out. As a rule only a very minimal clean up is required along the blanked out edges.



BLANKED OUT TOP OF CONTAINER

The very nature of rotational molding, that is the mold revolving on two axes simultaneously causes the outside corners to build up with an extra amount of material. This same action tends to cause thin outs on inside corners. This is particularly more pronounced with the liquid materials. It is easy to see that the material will have a tendency to run off the high points.



HEAVY MATERIAL BUILD-UP ON OUTSIDE CORNERS
LIGHT COATING ON INSIDE CORNERS

We have dwelt mostly on the properties of the individual cavities. Many times the person new to rotational molding will have apparently considered all the problems involved with the single cavity but he has not considered the problems involved in mounting a number of cavities on one spider or frame. This is often the part of the tooling program that the processor believes that he can do in his own plant. I wish to emphasize that the mounting of the cavities is every bit as important as the design of the cavity itself. Cavities can be hand fitted and matched perfectly but if the mounting is not properly done there will be an excessive amount of flash and a great amount of wear and tear on the cavities. The constant heating and cooling of the molds and the sticking of parts does put a terrific strain on the spider. For those people who have not had previous experience in mounting cavities I strongly urge that you go with the professionals at least until some experience has been gained.

It is a well known fact that where new equipment is being used more down time is caused by faulty or broken molds than by machinery malfunctions. The more sophisticated machinery on the market may be used but the part that is molded will be no better than the mold. There are many clamps and quick releases available for holding spiders together but we believe that strategically placed hold down bolts are still the most sure method. The nature of the finished part has much to do with the method used in holding the cavities together. Concessions have to be made whether or not you elect to securely bolt the spider together or if toggle clamps are used. The bolts take slightly longer but there will be less secondary operation in trimming parts. If the part does not call for a clean parting line, then a quicker clamping device might be more appropriate.

With the jumbo size molding machines emerging from the drafting tables the mold makers are also looking to the future We foresee the molds for these very large products being a combination of casting and fabrication. In our concept of things to come we believe that the parts will be of such size and value that it might take hours to assemble and disassemble the molds. The large construction modules will require hundreds of pounds of material per shot. It will be imperative that scrap be held to an absolute minimum. To assure the quality that is demanded of these parts the molds must be designed so that there is no room for error. There are unlimited possibilities for the rotational molding industry. If the men with the vision can become associated with the corporations with the resources then we will witness some very exciting developments.

For many years the plastic product has had the stigma of being a cheap substitute. It has taken much hard work and a concerted effort to bring the plastic industry up to the standard of respectability that it now enjoys. I would like to admonish all present who are interested in rotational molding to emphasize the great advantages of this process and not to let it become known as the cheap substitute for the other plastic processes. Yes we can use a $1.98 garbage can as a mold but let's set our sights much higher and show the rest of the industry that we are progressive in our technology and sound economically.