4. Rotational Molding

Introduction

Rotational molding, known also as *rotomolding* or *rotocasting,* is a process for manufacturing hollow plastic products. Although there is competition from blow molding, thermoforming, and injection molding for the manufacture of such products, rotational molding has particular advantages in terms of relatively *low levels of residual stresses* and *inexpensive molds*. Rotational molding also has few competitors for the production of large (> 2 m^3) hollow objects in one piece. Rotational molding is best known for the manufacture of tanks but it can also be used to make complex medical products, toys, leisure craft products.

Currently, the rotational molding industry is in an exciting stage in its development. The past decade has seen important technical advances, and new types of machines, molds, and materials are becoming available. The industry has attracted attention from many of the major suppliers and this has resulted in significant investment. Important new market sectors are opening up as rotational molders are able to deliver high quality parts at competitive prices. Nowadays a range of materials such as nylon, polycarbonate, ABS, high impact polystyrene and polypropylene can be moulded but by far the most common material is polyethylene.

The process is attractive for a number of reasons:

- It is a low pressure process the moulds are generally simple and relatively inexpensive.
- The moulded articles can have a very uniform thickness, can contain reinforcement.
- The moulded articles are virtually strain free and their surface can be textured if desired.

The use of this moulding method is growing steadily because although the cycle times are slow compared with injection or blow moulding, it can produce very large, thick walled articles which could not be produced economically by any other technique. Wall thicknesses of 10 mm are not a problem for rotationally moulded articles.

In overall terms the disadvantages of rotational moulding are:

- Its relative slowness
- The limited choice of plastics which are commercially available in powder form with the correct additive package.

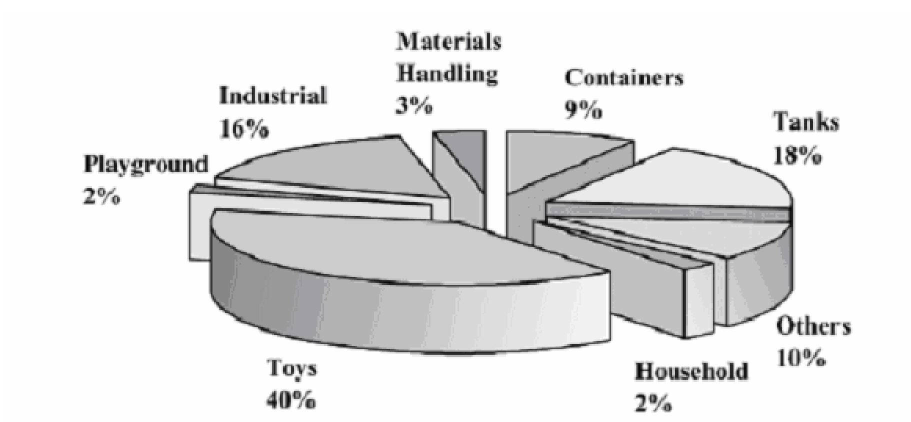
However, the advantages of rotational moulding in terms of stress-free moulding, low mould costs, fast lead times and easy control over wall thickness distribution (relative to blow moulding) means that currently rotational moulding is the fastest growing sector of the plastics processing industry.

Developments in rotational moulding are continuing with the ever increasing use of features such as:

(i) Mould pressurization (to consolidate the melt, remove pin-holes. Reduce cycle times and provide more consistent mould release),

(ii) Internal heating/cooling (to increase cycle times and reduce warpage effects).

The toy industry took to the process in a big way and, as shown in Figure 1, today this sector still represents over 40% of the consumption in that part of the world. Other typical applications for rotationally moulded products are presented in the table.



The Process

The principle of rotational molding of plastics is simple. Basically the process consists of introducing a known amount of plastic in powder, granular, or viscous liquid form into a hollow, shell-like mold. The mold is rotated and/or rocked about two principal axes at relatively low speeds as it is heated so that the plastic enclosed in the mold adheres to, and forms a monolithic layer against, the mold surface. The mold rotation continues during the cooling phase so that the plastic retains its desired shape as it solidifies. When the plastic is sufficiently rigid, the cooling and mold rotation is stopped to allow the removal of the plastic product from the mold. At this stage, the cyclic process may be repeated. The basic steps of (a) mold charging, (b) mold heating, (c) mold cooling, and (d) part ejection are shown in Figure 2.

Typical Applications for Rotationally Molded Products

Tanks	
Septic tanks	Chemical storage tanks
Oil tanks	Fuel tanks
Water treatment tanks	Shipping tanks
Automotive	
Door armrests	Instrument panels
Traffic signs/barriers	Ducting
Fuel tanks	Wheel arches
Containers	
Reusable shipping containers	Planters
IBCs	Airline containers
Drums/barrels	Refrigerated boxes
Toys and Leisure	
Playhouses	Outdoor furniture
Balls	Hobby horses
Ride-on toys	Doll heads and body parts
Materials Handling	
Pallets	Fish bins
Trash cans	Packaging
Carrying cases for paramedics	
Marine Industry	
Dock floats	Leisure craft/boats
Pool liners	Kayaks
Docking fenders	Life belts
Miscellaneous	
Manhole covers	Tool boxes
Housings for cleaning equipment	Dental chairs
Point-of-sale advertising	Agricultural/garden equipment

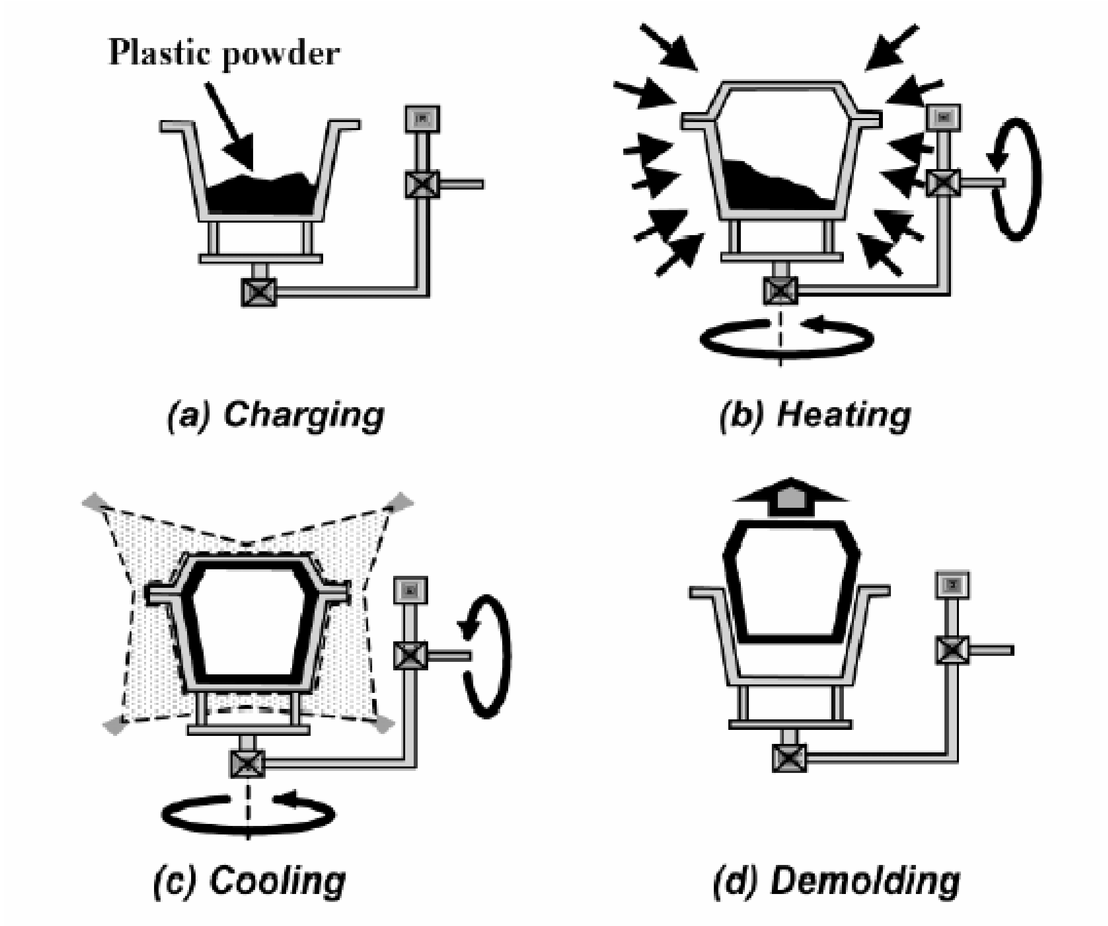


Figure 2 Principle of rotational molding

There is a variety of ways in which the cycle of events described above may be carried out. For example, in some cases (particularly for very large articles) the whole process takes place in one oven. However, a more common set-up is illustrated in Fig. 3. The mould is on the end of an arm which first carries the cold mould containing the powder into a heated oven. During heating the mould rotates about the arm (major) axis and also about its own (minor) axis (Fig. 4). After a pre-set time in the oven the arm brings the mould into a cooling chamber.

The rate of cooling is very important. Clearly, fast cooling is desirable for economic reasons but this may cause problems such as warping. Normally therefore the mould is initially cooled using blown air and this is followed by a water spray. The rate of cooling has such a major effect on product quality that even the direction of the air jets on the mould during the initial gradual cooling stage can decide the success or otherwise of the process. As shown in Fig. 2 there are normally three arms (mould holders) in a complete system so that as one is being heated another is being cooled and so on. In many machines the arms are fixed rigidly together and so the slowest event (heating, cooling or charging/discharging) dictates when the moulds progress to the next station. In some modem machines, the arms are independent so that if cooling is completed then that arm can leave the cooling bay whilst the other arms remain in position.

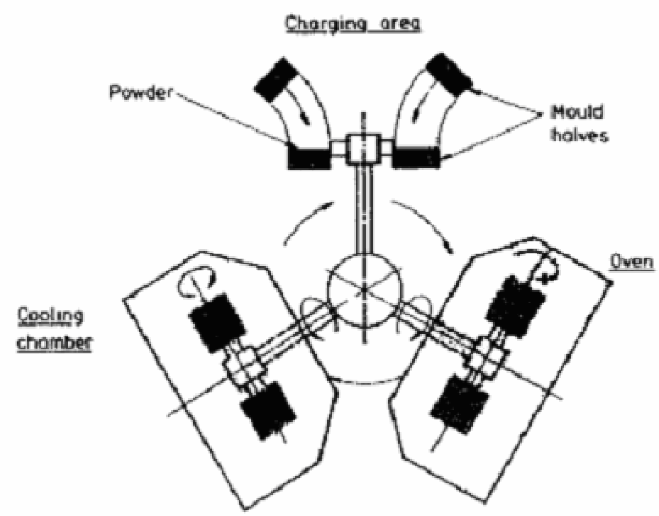


Fig. 3 Typical rotational moulding process

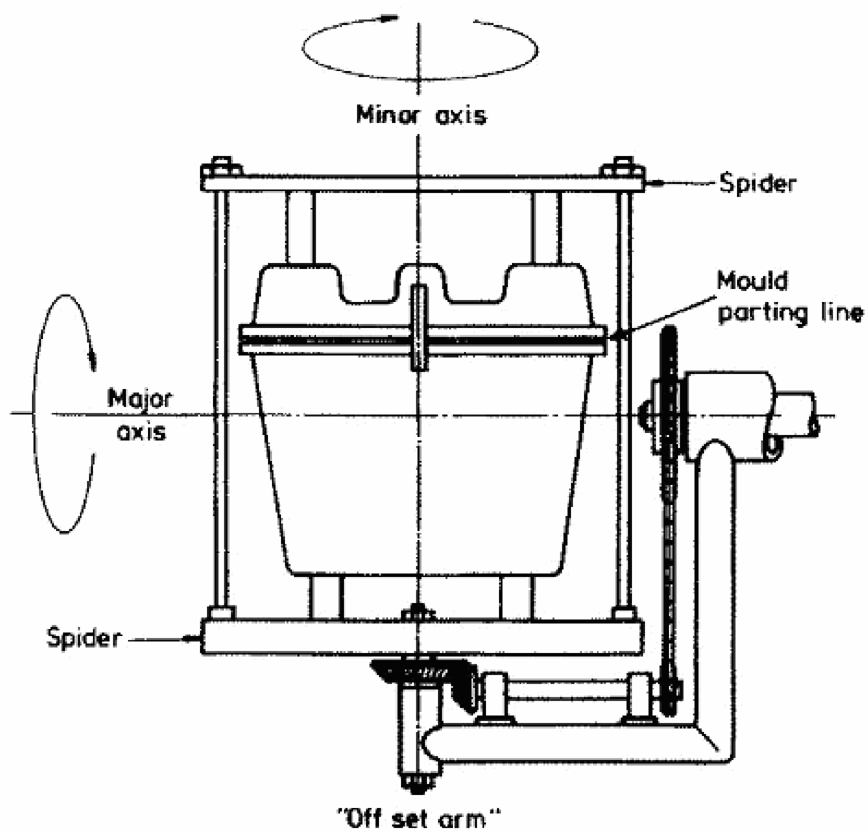


Fig. 4 Typical off-set arm rotation

It is important to realize that rotational moulding is not a centrifugal casting technique. The rotational speeds are generally below 20 rev/min with the ratio of speeds about the major and minor axes being typically 4 to 1. Also since all mould surfaces are not equidistant from the centre of rotation any centrifugal forces generated would tend to cause large variations in wall thickness. In fact in order to ensure uniformity of all thickness it is normal design practice to arrange that the point of intersection of the major and minor axis does not coincide with the centroid of the mould.

Rotational Moulds Heating

The heating of rotational moulds may be achieved using:

- Infra-red
- Hot liquid
- Open gas flame or hot-air convection.

However, the latter method is the most common.

The oven temperature is usually in the range 250 - 450°C and since the mould is cool when it enters the oven it takes a certain time to get up to a temperature which will melt the plastic. This time may be estimated as follows:

When the mould is placed in the heated oven, the heat input (or loss) per unit time must be equal to the change in internal energy of the material (in this case the mould).

$$hA(T_o - T) = \rho C_p V\left(\frac{dT}{dt}\right)$$

Where:

h is the convective heat transfer coefficient

A is the surface area of mould

T_o is the temperature of the oven

T_t is the temperature of the mould at time t

ρ is the density of the mould material

C_p is the specific heat of the mould material

V is the volume of the walls of the mould

t is the time

Rearranging this equation and integrating then

$$hA\int_0^t dt = \rho C_p V \int_{T_i}^{T_t} \frac{dT}{(T_o - T)}$$

$$hAt = -\rho C_p V \log_e \left(\frac{T_o - T_t}{T_o - T_i} \right)$$

$$\left(\frac{T_o - T_t}{T_o - T_i} \right) = e^{-h\beta t/\rho C_p}$$

Where T_i is the initial temperature of the mould and is the surface area to volume ratio (*A/V*). This equation suggests that there is an exponential rise in mould temperature when it enters the oven, and in practice this is often found to be the case.

Example:

How long does it take an *aluminum cube mould* 330 mm side and 6 mm thick to melt a sample of polypropylene in a rotational process using the following typical values of oven temperatures and data? Do the same calculation for a mould made from steel.

	Aluminum	*Steel*
T_o	*300°C*	*300°C*
T_i	*30°C*	*30°C*
T_t	*20°C*	*20°C*
h	*22 W/m²K*	*11 W/m²K*
C_p	*917 J/kgK*	*480 J/kgK*
ρ	*2700 kg/m³*	*7850 kg/m³*