Chapter 5 Rotational Molding Tools

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1 Description of the Process

For economical production of seamless plastics hollow articles, the processor can choose between the well-known methods of blow molding and rotational molding[1]. Raw materials in paste or powder form are used for rotational molding. Originally rotational molding was limited to flexible PVC. Nowadays hollow-article production in polyethylene, polycarbonate, cellulose ether and nylon is part of rotational molding's technical curriculum. In all these cases the plastics material is fed into the single or multiple rotational mold in precisely measured amounts. For a given part size and surface geometry the amount of raw material charged determines the wall thickness of the hollow article. The charged mold, closed by toggle clamps, is fastened to mold carriers, which in turn are connected to the machine arms and driving components. The design of these components is guided by the various concepts of the individual machine manufacturer. The most important design characteristic is that the molds be able to rotate slowly around the two axes, which are at right angles to each other. Rotating usually takes place in an oven at 300 °C. Hot air or flame heating is also often used; other machines operate with oil heated/cooled molds at temperatures of up to 300 °C. These plants distinguish themselves through good controllability. However, expensive jacketed molds are required. After rotation in the hot-air oven, usually lasting for five to 10 minutes, the mold and part are cooled down to demolding temperature in a cooling station by spraying with water or submerging in a water bath. Because multistation plants are employed for economical production, raw material charging and demolding takes place during automatic operation in stations designed for just these purposes.

2 Mold Specifications

As can be gathered from the above description, rotational molds are subjected to extraordinary stress reversals during production sequences. During the process, molds are heated to over 300 °C and cooled down subsequently

[1] VDI-Richtlinie 2018 *Rotationsformen*, 1971.

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to almost ambient temperature, and that within a cycle of five to 10 minutes.

These extreme conditions must be borne in mind when choosing suitable mold-making materials. The molds must be made of good heat-conducting materials and must be as thin-walled as possible to save heating energy. But their own stability has to be chosen according to the centrifugal forces to be encountered. The connecting components between mold and mold carrier as well as the clamping devices have to be considered. The latter should be fast and safe in handling. The sealing tightness of the mold and closure or, in multiple molds, between the individual tools, is of importance. Leaks are a great disadvantage, as plastics material could escape during production, have a negative influence on the wall thickness of the part and bake onto the outside of the tool. The crust thus created is very difficult to remove and is heat insulating, thereby diminishing the uniform heat transference through the mold wall. Excessive flash on the parts can also be expected, resulting in high finishing costs. If water is allowed to enter the mold while it is in the cooling station, one can expect spotty parts that have to be scrapped. The surface quality and contour of the mold cavity is transmitted to the appearance of the part. The specifications of the article drawing (shaping of the contours with possible undercuts, surface quality, possibly graining structures) exert considerable influence on the choice of suitable mold-making materials and the most favorable manufacturing process. Even the process-determined requirements when converting PVC, PE, PA and polycarbonate or the corrosion problems arising from hydrochloric acid when processing PVC must be taken into account when deliberating about the design.

3 Mold Production

(a) Copper and brass sheet
(b) Light metal (cast aluminum)
(b) Electroplated molds

These are primarily employed as mold-making materials for rotational molding. The manufacturing methods are not only very different, they are specific for each material. Molds can also be produced by the metal spraying process, but this is of secondary importance only. It is very difficult to create sufficiently smooth surfaces with this method and molds produced with it are relatively brittle and porous and fracture easily. They can only be used for a limited number of parts.

3.1 Sheet metal molds

The production of large parts of PE, PA or polycarbonate, e.g., transport or storage containers of up to approximately 10,000 liters capacity, heating oil

tanks, packaging parts, furniture parts, boats, etc., usually requires molds consisting of several parts because demolding would otherwise not be possible. For parts with less difficult contours and single-cavity and jacketed molds (Fig. 1), molds in steel sheet are employed. The wall thicknesses are 2 to 4 mm. The individual sheet sections are welded or soldered; the flange on which the clamping device is mounted (Fig. 2) and the mountings for fixing the mold to the machine are also welded. Wherever possible the parting lines should be machine planed with both mold halves at working temperature. The weld or solder joints must be ground and polished. One is also subjected to the skill of the sheet metal worker, which perforce limits the achievable surface quality. Furthermore, the subsequent finishing costs tend to increase the mold costs. In almost every case, sheet metal molds are chosen for jacketed molds, although electroformed mold shells are employed with an external sheet metal jacket. This external jacket must be supported as shown in Fig. 3, apart from the fixture on the flange.

The spacers should effectively be fitted at distance of approximately 200 mm.

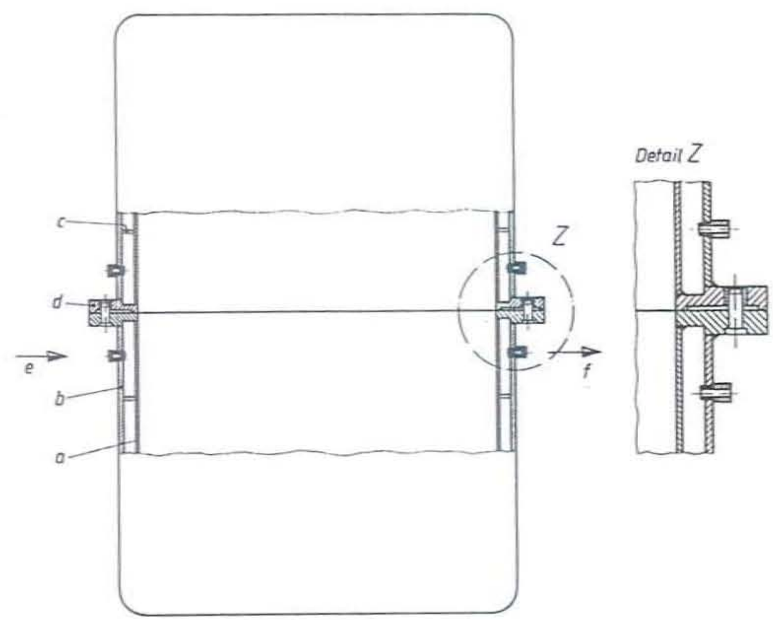


Fig. 1. Principle of construction for a jacketed mold.
(*a*) Internal wall, (*b*) external sheet metal jacket, (*c*) support, (*d*) flange, (*e*, *f*) inlet and outlet for heating medium.

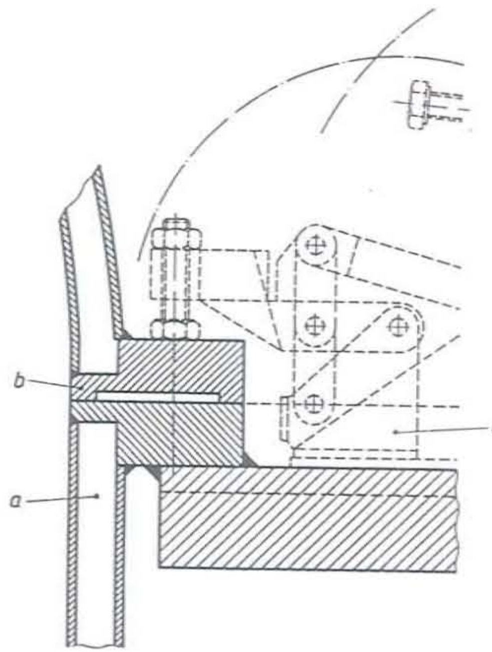


Fig. 2. Mechanical closing device on jacketed molds.

(*a*) Mold, (*b*) flange, (*c*) swiveling clamping device.

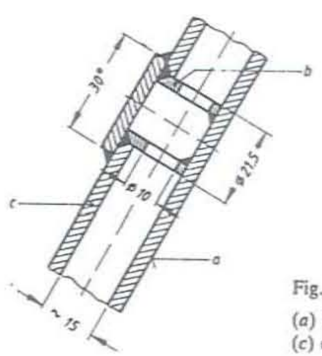


Fig. 3. Support in a double-walled mold.

(*a*) Internal contour of mold, (*b*) spacer, (*c*) external sheet metal jacket.

Figure 4 shows the structure of a pressure-equalizing tube in a jacketed mold. This tube is mandatory for all rotational molds producing closed hollow bodies, regardless of whether they are single- or double-walled tools, with the exception of PVC processing. This tube is also used as a raw material filler tube.

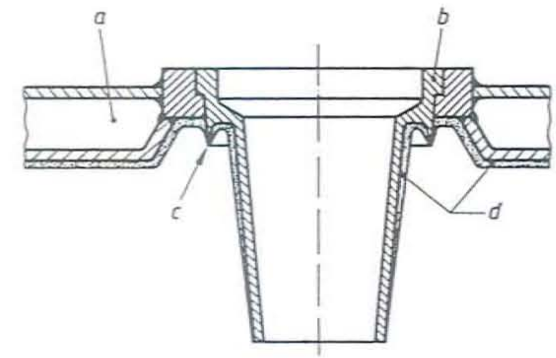


Fig. 4. Dipping tube in a jacketed mold.

(*a*) Jacketed mold, (*b*) pressure-equalizing tube, (*c*) safety break point, (*d*) part.

On occasion inert gas is fed through the opening to prevent oxidation during the melting of plastics materials.

3.2 Light-metal molds

Mass production of balls, small containers, etc., requires a supply of rotational molds manufactured quickly and cheaply. The use of cast aluminum molds is of particular advantage in this case (Fig. 5). Compared to sheet steel molds, wall thicknesses of approximately 10 mm become necessary for reasons of rigidity, but the superior heat conductivity of the aluminum balances this again. Light-metal foundries are nowadays able to include not only the necessary flanges and fixtures in their castings but also can produce such surface effects as the markings on footballs.

However, high-gloss surfaces cannot be achieved with light-metal molds. For the production of large hollow articles (as described in Sec. 3.1) cast aluminum molds are also employed, but preferably as single-walled tools. The usual wall thicknesses in this instance are 10 to 15 mm but more in some cases to ensure the self-supporting rigidity of the mold. Often with complicated surface structures there is the hazard of creating voids and the possibility of microporosity in cast aluminum.

Water could reach the interior of the mold through these pores during the production run and cause spotting. Close checking is therefore advisable, possibly with a pressure test after casting or finishing.

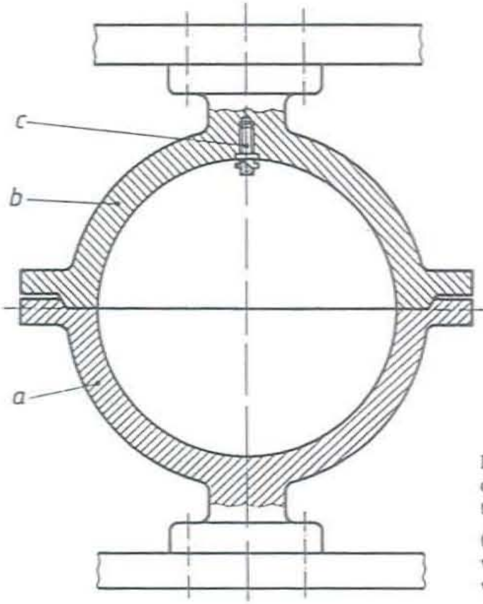


Fig. 5. Two-part rotational mold of cast aluminum for the production of balls.

(*a*) Lower part, (*b*) upper part with insert plug, (*c*) for forming valve opening.

3.3 Electroforming

Electroformed rotational molds still constitute the largest number of molds employed in rotational molding. (Electroforming has become an accepted term now and will be used throughout this chapter.) Their usage is not just limited to the production of PVC parts; they have become part of standard technology for the production of small and large parts in PE and PA as well (Fig. 6).

The preferential position occupied by electroforming among the various production processes for rotational molds is based on the following advantages:

(a) The material combination of nickel and copper guarantees corrosion resistance and good heat conductivity.
(b) Thin-walled molds can be produced with uniform wall thicknesses.
(c) Almost every molding structure is reproducible.
(d) Random surfaces can be reproduced.
(e) By using casting-resin models or sample cast parts exact replica production molds can be made.

Electroforming is described in detail in Chapter 15. Here we wish only to highlight the particular specialities relating to rotational molds.

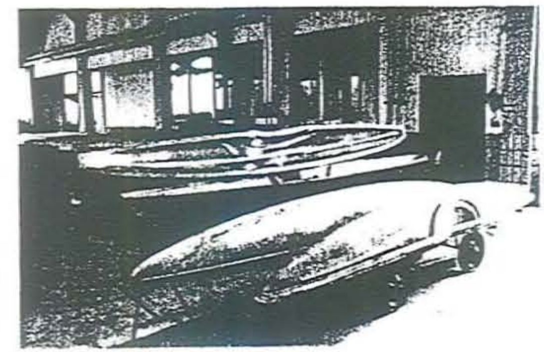


Fig. 6. Two-part electroformed shells (with bath models) for the rotational molding of kayaks in PE.

During the electroforming process the model is copied down to the last detail. The male model for the bath, which is identical with the part to be produced, is therefore the basis for the electroforming production of rotational molds.

At this stage all the required details such as dimensional tolerances, surface quality, etc., already have to be determined. Through the precise duplication when electroforming, it is possible, for instance, to produce rotational molds for artificial limbs whose internal molding surface is a precise reproduction of human skin.

The model specifications are very strongly influenced by the processing methods to be employed. The usual parts in PVC, for example armrests for cars (Fig. 7), bicycle saddles, toy animals and display dummies, almost always show the same undercuts. As very often only single-part molds are employed, demolding of the PVC article takes place out of relatively small openings, which does not present any great difficulties owing to the flexibility of PVC.

Demolding of the models used for electroforming has to take place through the small mold openings. For this reason model-making materials have to be used that can be destroyed mechanically or chemically. The situation changes with multiple rotational molds. Demolding is easier in this instance, so that even the models can be produced by the usual method in casting resins (Fig. 8).

On the assumption that several molds are required for mass production, the bath models are executed as follows. A master model is fashioned first. With parts of dolls, toy animals and artificial limb covers (decorative hands for jewelry display) these masters are modeled in a suitable wax or a cast is made of a human body part.

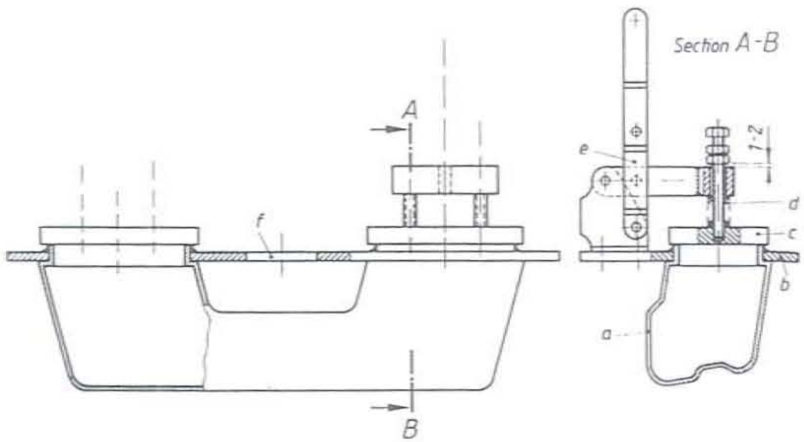


Fig. 7. Electroforming with clamping device for the rotational molding of car armrests. (*a*) Electroform, (*b*) soldered-on retaining flange, (*c*) aluminum lid, (*d*) heat-resistant dished springs, (*e*) quick clamps (toggle levers) available in the trade, (*f*) channels for improved heat conduction.

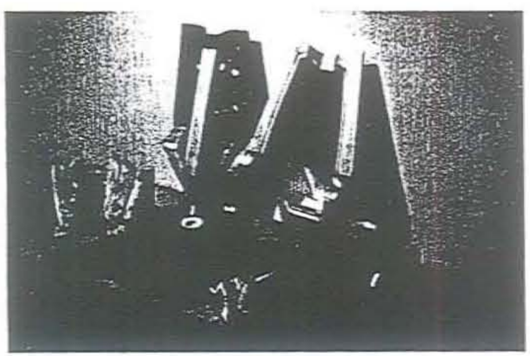


Fig. 8. Two-part electroform with bath models and a motorbike tank molded in PA.

A master mold is made from the master model by electroforming. The required number of individual models are rotationally molded, from which the mass-production molds can be made. For this purpose thick-walled, rigid PVC parts are normally produced. If required, these PVC models can be strengthened by filling their interiors with casting resin or wax. It must be noted, however, that for this type of model-copying process it is necessary to take twice the shrinkage into consideration when producting the master model. It has also proved of some purpose to add already to the master molds extensions, truncated cones and other shapes required for the clamping system to be installed. These contours are transferred to the mass-production molds from the PVC models.

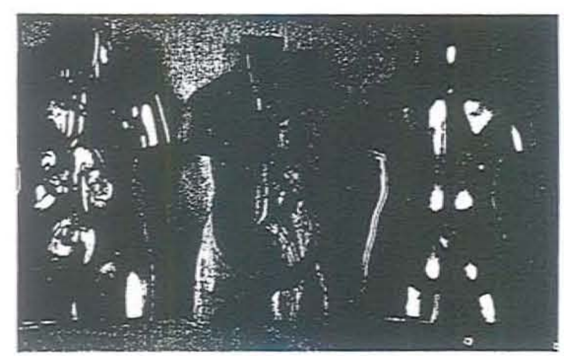
The working sequence described can also be chosen for car armrests, but in a somewhat altered version. As the car industry puts great emphasis on dimensional accuracy and surface quality the following method is preferred to the one described above, whose models are rather delicate in some respects:

Here one also starts off with a master model, which is produced from layers of wood, however, by a model maker. This master model has leather or leather-grained film stuck on it whose seams are smoothed over with wax or fillers. Then a single or multiple silicone-rubber negative is taken off. To overcome dimensional fluctuations and the well-known instability of the silicone rubber, cast resin support shells are used, in which the silicone rubber can take a foothold.

Depending on the molding contours, up to approximately 10 bath models can be taken off one silicone cavity in epoxy or polyester resin. Due to the demoldability of the models from the finished electroformed molds, hollow molds are required that assist chemical dissolving. Naturally, a great number of other models are also cast according to this method, e.g., bicycle saddles, car horn buttons, vacuum cleaner containers and car seats. Medical lecture material in PVC (Fig. 9) is cast in the majority of cases in two- or multiple-part tools. Cast resin models that have been molded from silicone negatives are used here as well. The parting plane is wavelike as a rule and is also molded and receives locating means, e.g., tongue and groove, so that the two mold halves fit together precisely and without movement.

The male bath models are equipped with the required fixtures, fitted with supply contacts and then have to be cleaned carefully before being made

Fig. 9. Front and back side of an electroformed mold for producing anatomical models in PVC, in this case a female torso.



electrically conductive by applying a silver coating. The silver-coated model acts as cathode during plating.

By using suitable electrolytes copper or nickel is deposited on the cathode to the required thickness—similar to the familiar surface plating process. For small- and medium-sized molds a wall thickness of 2 to 2.5 mm is ideal. The galvanizing process in this case takes two to three weeks—a little longer for large molds and greater wall thicknesses. Once the required thickness has been obtained the fixtures and supply contacts are removed, the model is demolded and the electroformed mold issues as the negative reproduction of the male model. To make it functional only the mounting components and the clamping devices have to be fitted.

To avoid difficulties it is customary nowadays to produce electroform molds in nickel or hard copper. To this end a nickel layer of approximately 1 to 1.5 mm thick is produced first and is then reinforced by an approximately 1 mm thick layer of hard copper. Depending on the usage of the electroformed molds, brazable sulfamatic nickel or hard nickel of 45 to 55 Rockwell C is chosen. Hard nickel is particularly chosen for multiple molds for PE and PA processing.

By employing screens and auxiliary anodes local wall thicknesses can be increased as required by the mold design, e.g., flanges on multiple molds. The plating-in of steel or nickel pieces for housing mounting components is also possible.

Difficulties with brazing of fixtures have been overcome during recent years. Blisters used to form in the nickel and copper layers at the high temperature of the electroforming process. With the correct choice of electrode and an exact timing of the individual working stages an electroformer can produce almost any required mold by this method at present.

3.4 Fixtures and clamps

Fixtures for mounting the rotational mold generally have to be provided. With electroformed molds supporting ribs or take-up flanges are often required, which apart from the task of connecting the mold also serve to prevent distortion (Fig. 7), and they are required for mounting the clamps. These components are fastened to the mold walls rigidly by brazing in every case, and they influence heat transference. By choosing angle iron, perforated sheet, thin flat stock, etc., the heat capacity of these fixtures and supports is kept as low as possible. They also are fitted at places where the increase in wall thickness does not matter.

For clean and efficient operation the closures used on rotational molds must be fast and reliable in use without leaking. For simple flat machined mold openings as on car armrests and toy figures, flat aluminum covers are used that can be moved and kept closed by toggle clamps available in the trade. The aluminum covers are connected with the moving lever arm of the

fast clamping device through adjustable bolts. In many cases additional springs are used to compensate for small angle deviations. But it is of absolute importance to take heat resistant springs for this purpose, as standard ones relax too soon. For other mold designs, screw closures, clamping braces or eccentric clamping means are chosen. In each case the clamping force of the clamping means must suit the mold size and the design of the sealing surface.

Should sealing problems due to unfavorable heat expansion occur, however, despite careful design of closing systems and clean sealing surface machining, sandwiching of chloroprene rubber, silicone rubber or PTFE usually remedies these shortcomings in practice.

With many molds the clamping fixtures, apart from fulfilling sealing requirements, help with the actual molding. Bayonet closures are of advantage with single molds, whereas in-line molds are kept closed by a tensioning clamp and spring balance (Fig. 10). Rotationally symmetrical bungs that close the mold opening securely through conical sealing surfaces are used for doll components. These bungs, which intrude into the rotational mold with their front parts, are shaped to the respective mold contours to form the connections for head, arms and legs on parts for dolls, for instance (Fig. 11).

If problems are expected with the demolding of PVC parts, action can be taken in the following manner: the sealing lid can be shaped in such a way by the incorporation of a projecting mandrel that it causes an indentation in the PVC part. This is closed off by only a thin skin that can easily be penetrated.

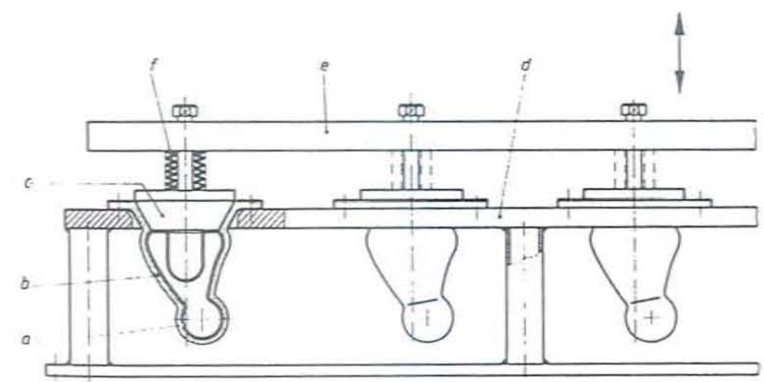


Fig. 10. Rotational in-line mold.

(*a*) PVC article (toy), (*b*) electroformed mold, (*c*) aluminum bung, conical with molding piece, (*d*) support rack, (*e*) mechanically or pneumatically driven clamping device, (*f*) pressure-balancing springs.

Fig. 11. Electroformed mold for the production of dolls' legs in PVC. With aluminum bung and single bayonet closure.

The demolding tool consists of a hollow needle that is introduced through the indentation. A hose with a three-way tap is connected to the hollow needle. Once the thin skin has been penetrated vacuum can be switched to the needle through the three-way valve. Compressed air can be brought in via the third line to remove any possible distortions. A demolding temperature of 50° C is essential.

A similar indentation produced with a mandrel serves to house the air valve on balls and the "squeaker" on toys.

3.5 General

The specifications for the surface conditions of the electroformed molds are quite varied. Matt silk surfaces are requested for doll parts and toy animals. The usually severely undercut electroform molds are sandblasted with corundum for this reason. Leather-grained or smooth surfaces are successfully blast treated with glass spheres using the dry or the wet method. Various sizes of glass spheres are available to suit the surface smoothness required.

Despite the most careful mold layout the walls of molded parts may become uneven. In practice this can be overcome by fitting auxiliary sheet metal baffles or by coatings with aluminum paint.

Plastics or steel insert parts can be blended into the walls of the moldings. They have to be prewarmed to the starting temperature of the mold, however. It is important that the retaining spigots necessary for the retention of the inserts be installed properly so that no plastics material can escape from these locations during rotation.

4 Special Processes

Development in the field of rotational casting and similar related processes is still continuing. New technologies and larger dimensions are constant challenges for the electroformer and the toolmaker.

Figure 12 shows an electroformed shell for a car seat produced with a method in which the original "slush molding process" has come to new life again in a different shape (in conjunction with containers).

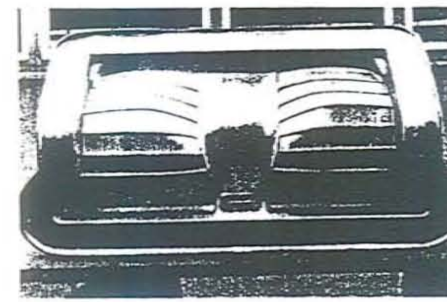


Fig. 12. Electroformed mold (for a twin seat in a car, PVC) for use as a container mold.

Literature

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