

Hybrid Processing for Producing Functional Thin-Walled, Transparent Parts

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Abstract

There is a need for a method that can produce small production quantities of thin-walled, transparent parts for end use and product development purposes. Existing methods, such as blow molding and rotational molding, require expensive tooling as well as significant labor. Reducing these costs is important for short-run production and prototypes. This research explores the feasibility of a new method to produce transparent hollow parts, which combines several manufacturing methods in a hybrid approach (additive, subtractive, and net cast). This process initially uses patterns produced by hand or additive manufacturing (rapid prototyping) and concludes with a small quantity of functional plastic parts. The advantages of this process are that any shape can be used; there is a reduction in cost as well as in labor effort; anywhere from one to thirty parts can be created in a term of five days, and the parts will have good surface finish as well as clarity.

Keywords: Hybrid Processing; Rapid Prototyping; Cured Coating Method

1. Introduction

1.1 purpose

This research proposes a new method to fabricate any type of hollow plastic object. Experiments were completed to prove that several manufacturing methods could be combined to obtain one or several final products that could be used for end-use or prototyping purposes. The method combines several manufacturing processes in a hybrid approach -additive, subtractive, and net-cast-. The main purpose of this investigation was to reduce several factors that are important in manufacturing; these factors include initial prototyping cost, lead-time, and time spent in labor.

1.2 scope

After analyzing a series of conventional manufacturing processes, such as blow molding and rotational molding, a method called Cured Coating became the best option. The Cured Coating Method combines several manufacturing process in a hybrid approach and can be considered a feasible method to create any type of hollow transparent object. Some factors that determined that the Cured Coating Method was promising were cost, lead-time, and labor. Reproducing the form of a plastic bottle was one of the most important concerns, accompanied by obtaining optical clarity. General characteristics such as stiffness, flexibility, and strength also had to be produced. Threading, accuracy on dimensions and wall thickness was not taken into account in this research.

1.3 background

The bottle making industry has a significant problem with the existing techniques of manufacturing bottles when producing prototypes. There is a tremendous waste of cost and time that could be reduced if a new method were to be applied. Another problem of the industry is the lack of clarity as well as the labor involved in creating one or multiple realistic rapid prototype bottles. This same problem can be applied to any industry that creates any type of thin-walled objects.

1.3.1 hybrid processing

Hybrid processing is a selective combination of additive (rapid prototyping), subtractive (drilling, EDM machining, CNC machining) and near net-shape (casting, molding) manufacturing processes. It is used to create complex, three-dimensional structures. Hybrid synthesis and fabrication of advanced articles provide a significant opportunity with its multifaceted applications in different areas of engineering.

1.3.2 rapid prototyping and stereolithography apparatus

Rapid prototyping (RP) is a technology that is used to build an object by layers directly from a computer file using specialized machinery [1]. Rapid prototyping is accurate in dimensioning which makes it an effective in creating parts with complex geometries

Stereolithography is an excellent process for producing fast and accurate parts. The SLA apparatus (Figure 1B) functions in the following manner; the apparatus consists of a vat of photosensitive liquid resin and an ultra violet laser arrangement. Using a stereolithography format (.stl), a list of triangular surfaces will be interpreted by a computer that will generate a solid model [2]. The solid model is sliced into two-dimensional cross section layers; each layer is later drawn onto the surface of the vat containing photosensitive liquid resin. When this resin is exposed to the ultra violet laser the resin cures and the pattern is traced. After the completion of a layer the platform moves down into the vat, and a new layer is added. This is done as many times as needed until the solid model is complete (Figure 1A) [3].

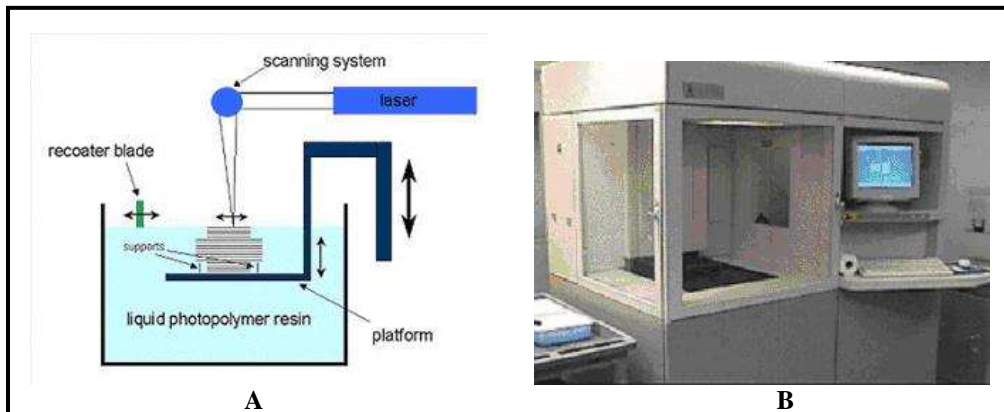


Figure 1 A) Stereolithography Process [4] B) Figure 2 SLA 5000

2. Materials

Three types of materials were used in this project: RTV silicone rubber, paraffin wax, and water-clear polyurethane that are explained in the following sections.

2.1 room temperature-vulcanizing (RTV) silicone

Silicone rubber is a material that has high thermal resistance. It can reach temperatures as high as 600°F (316°C) without suffering any permanent distortions [5]. Silicone rubber is an effective material when it comes to producing molds, for that reason molds are simple to create and control. They have beneficial characteristics such as flexibility, durability, weather resistance, fatigue and compression set resistance, as well as low tooling costs.

2.2 water-clear or transparent polyurethane

Polyurethanes are a combination of polyol (an alcohol with more than two reactive hydroxyl groups per molecule) with a diisocyanate or a polymeric isocyanate. Because of the variety of these two substances polyurethanes can range from a Shore A hardness (soft) to a Shore D hardness (hard) on the Durometer Scale [6]. The diversity of hardness will allow the formation of specific polyurethanes for each need. An 84 Shore D polyurethane was chosen because it met the tensile modulus of polystyrene and polyethylene plastics which are the materials that are most commonly used in bottle fabrication.

2.3 paraffin wax

Paraffin wax, also known as candle wax, is the lowest temperature melting wax (100°-200°F). It is solid at ambient temperature; it is a thermoplastic and insoluble in water [7].

3. Objective

The objective of this research was to test the feasibility of a new method to produce transparent hollow parts, which combines several manufacturing methods in a hybrid approach (additive, subtractive, and net cast).

4. Approach

The Cured Coating Method was the most effective combination of manufacturing processes to produce the thin-walled, transparent part. The method follows a series of six steps to obtain the final product.

The Steps:

- Step 1: prepare pattern
- Step 2: room temperature vulcanizing molding
- Step 3: expendable wax core
- Step 4: RTV coating
- Step 5: water-clear polyurethane coating
- Step 6: paraffin wax and RTV liner removal

5. Results

The Cured Coating Method was the method used to obtain the final plastic bottle. The process is explained step by step further on.

5.1 step 1: prepare pattern

The first step is to obtain a pattern. In this research, a bottle was designed on SolidWorks®. The bottle had determined dimensions and some detailed features placed on the surface (Figure 2A and 2C). The features were placed on the bottle to prove that small details are capable of being reflected on the final product. The bottle was then adjusted for minor details such as interior and surface finish on RP Magics. The bottle pattern was built on the SLA 5000 machine (Figure 2F). This step is the additive part of the hybrid fabrication since there is an addition of layers when building the bottle.

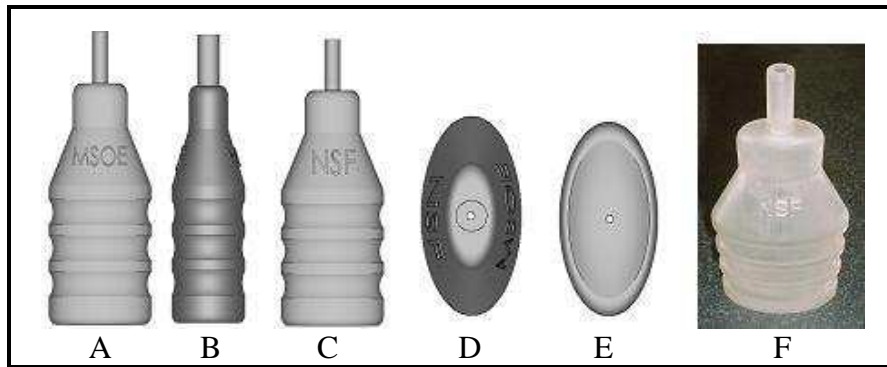


Figure 2 Bottle Pattern created on SolidWorks® and RP Magics A) Front View, B) Side View, C) Back View, D) Top View, E) Bottom View, F) Final Bottle Pattern.

5.2 step 2: room temperature vulcanizing molding

A room temperature vulcanizing (RTV) mold was prepared. The process of creating an RTV mold is rather simple and straightforward. A mold container built out of polystyrene and acrylic was first constructed and the pattern built on the SLA 5000 was placed within this container. A mixture of rubber silicone and hardener with a ratio of 10:1 was poured into the container. The rubber covered the part completely encasing the pattern. By splitting open the rubber mold the original part was removed and the mold was set for production (Figure 3). The details of the bottle were reproduced exactly onto the RTV mold.

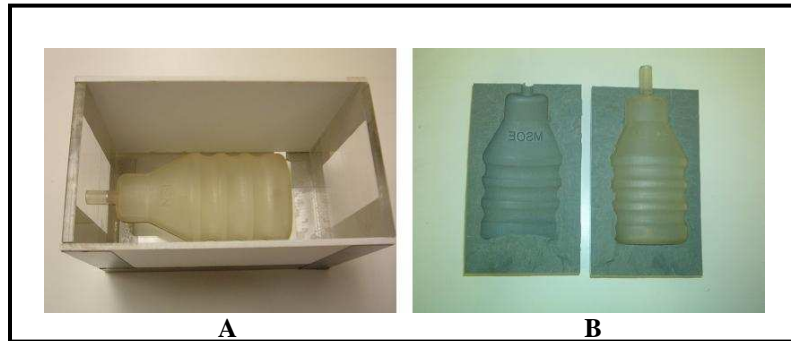


Figure 3: A) SLA Pattern in Box B) Pattern in Rubber Silicone Mold

5.3 Step 3 expendable wax core

The third step was to fill the mold cavity with paraffin wax. The solid paraffin wax was melted in an oven at a temperature of 125°F. Once the wax was completely melted a funnel was placed in the top opening of the rubber mold to allow the passage of the wax into the cavity. Once the cavity was filled with the wax the mold was placed into a vacuum to release excess air bubbles. The wax then solidified at room temperature (Figure 4). This step is considered to be net-cast, which means there is a casting of a material.



Figure 4: Expendable Paraffin Wax

5.4 step 4: RTV Coating

The wax parts were coated with rubber silicone, which adhered onto the surface of the wax part (Figure 5A). Silicone has the advantage of acquiring fine details, which is beneficial for small and complex details on the bottle. This coating created a thin smooth rubber liner (Figure 5B).

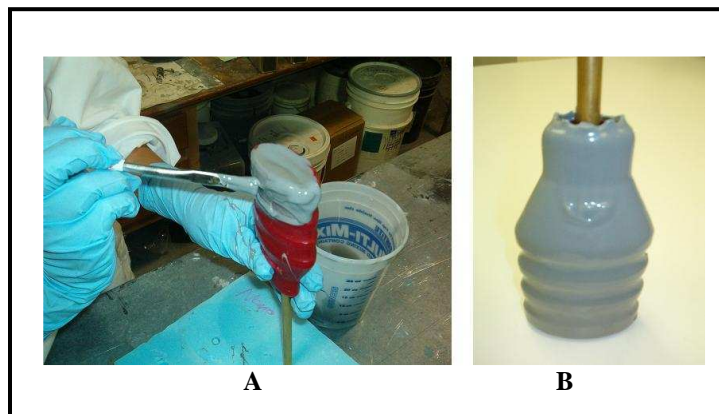


Figure 5: A) Coating of Wax with Rubber B) Coated Rubber Bottle

5.5 step 5: water-clear polyurethane coating

The rubber-coated wax goes through another step in this method. The part was coated with water-clear polyurethane. Water clear polyurethane comes in a two-part kit and has a pot-life of fifteen minutes. A small quantity of clear rubber was placed in the polyurethane to allow better adherence. The polyurethane as a mixture was coated onto the rubber coated wax (Figure 6) and was left at room temperature to cure.



Figure 6: Coating of Polyurethane

5.6 step 6: paraffin wax and RTV liner removal

Lastly, the entire part was placed in the oven set at 125°F that melted the wax, which flowed completely out of the bottle (Figure 7A). What remained inside were the thin rubber liner and the plastic formation. The rubber liner was peeled off the polyurethane part (Figure 7B). In the hybrid approach this was considered to be subtractive because material was removed from the final part. An optically clear polyurethane bottle remained with the correct strength, hardness, and flexibility desired (Figure 7C).

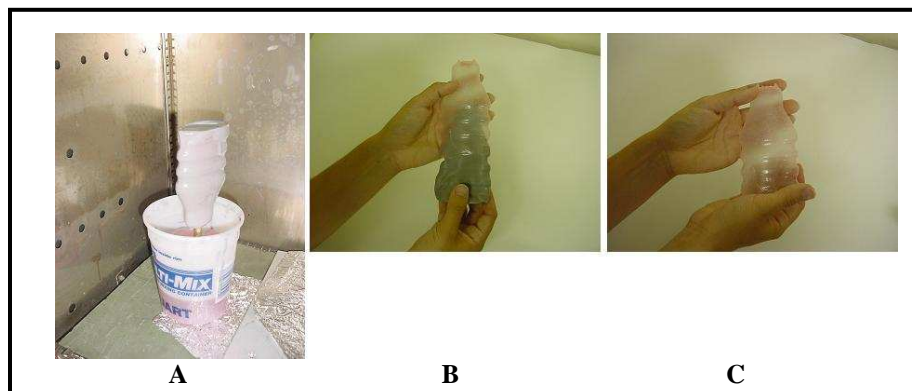


Figure 7: A) Melting of Wax B) Removal of Rubber Liner C) Final Bottle

6. Conclusion

The Cured Coating Method succeeded in each step and the result was the creation of a plastic bottle using non-conventional manufacturing processes in a hybrid approach. There are several factors that require improvement such as optical clarity and surface finish. Further research should be completed in these areas. The objective was met and the method proved to be feasible when needing to produce prototypes at an effective cost and time.

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