SPE BLOW MOLDING COMPETITION

BLOW MOLDED CUSTOMIZABLE TROPHIES

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ABSTRACT

Trophies are currently made by hand using various different types of materials to create these simple structures consisting of only a base, supports, a top tier platform and a figurine. Considering the large quantity of trophies needed by children’s sports teams and organizations around the country, a more affordable solution for ordering 100+ individually made identical trophies would be to order the same amount from a company that blow molds them, which is a much quicker and less costly alternative.

To blow mold a custom trophy, two-piece molds would first have to be made using removable pieces that serve as molds for individual aspects of the trophy (i.e. support tubes, figurines). The mold would then close around a piece of the chosen plastic and would receive the large inflow of air that constitutes the blow molding process. After some small manufacturing to add marble or wood bases, plaques, and finishing designs, the trophies would be ready to be shipped to their respective organizations.

INTRODUCTION

This design report will explore blow molding and the extension of its application to the creation of a custom designed trophy. Using two distinct standard models, a thorough discussion will be developed regarding the process of trophy blow molding including mold and tooling detailing, cost analysis, design specifications and more. All this will be done in a manner that accentuates the benefits of blow molding trophies in a process that allows many different sizes and types of trophies to be created in a quicker process.

BLOW MOLDING APPLICATION

The current process for building a trophy involves the separate creation of the parts by a manufacturer and then the assembling by a retailer. As it will be later discussed and shown in a cost analysis, the creation of a custom designed trophy can be expensive depending on the design and quantity ordered.

Blow molding has been proven to be able to produce large quantities of plastic products of consistent quality and has been used extensively by numerous industries for multiple applications ranging from food storage to waste disposal. By applying the blow molding process to trophy creation, it was discovered that a trophy could be easily blow molded as a single piece if the entire trophy was a hollow cavity. Since blow molding is also a much cheaper alternative to the current assembly process, it was determined that large quantities of trophies could be created in a faster, more cost efficient manner if blow molding was used.

STATEMENT OF THEORY AND DEFINITIONS

Organizations worldwide order trophies in mass quantities for a variety of reasons ranging from little league baseball recognition to advanced design competition achievement. By giving out trophies, team leaders have been able to recognize the success and achievements of their teams to boost morale. Trophies can also come in a variety of shapes and forms, such as cup trophies, single column trophies, tiered trophies, and 2, 3, or 4 column trophies. Though trophies for some sporting events (such as the FIFA World Cup and Super Bowl) could never be replaced by cheaper blow molded alternatives, participation trophies for office and recreational
sport uses could be blow molded in a process that would be more effective and cost efficient than the current manufacturing process.

Trophies are currently manufactured and then assembled by hand in shops. For our purposes, we'll be considering two simple trophy designs: a double tiered, double column trophy with a figurine on top and a single column, single tier trophy with a figurine on top. Both models can be shown below.

The double tiered trophy would consist of 9 independently manufactured parts using today's techniques: the figurine, the second tier, four check rings, two columns, and the base. Similarly, the single column trophy would consist of four parts: the figurine, column, check ring, and base. Each part is produced differently:

- Figurines are injection molded, a process where plastic pellets are melted and pressed through a die to create the form required.
- Bases are also injection molded, but then filled with gypsum to achieve the weight desired or needed to prevent the trophy from toppling.
- Columns are injection molded, and extruded into a long tubular shape, usually 48" long which are then cut into the required size for the trophy design.
- Any part that needs a metallic finish (such as the columns and the figurine) would then have metallic foils and finishes hot stamped onto them.

These pieces are packaged and sent to assemblers who cut down the columns into the prescribed sizes and use metal rods to align the columns, check rings, and bases. The figurines are then screwed onto the bases using some nuts. After some quality checks, alignments, and tightening, the trophy is complete.

Our design proposes a cheaper and more efficient alternative to creating mass quantities of trophies. Manufacturers would use a mold with interchangeable parts for the blow molding process, allowing for the trophy to be completed in one piece. When a new design is ordered, the manufacturer can simply change out the parts in the mold to the ones required by the design and continue production.
DESIGN DETAILS

The overall dimensions of height and width of the blow molded trophy were based off of common sizes for trophies manufactured by hand. Other design details were chosen to ensure the success of a blow molded product. For a successful blow molded product, it is desirable to have a blow ratio where the depth is greater than the width because it ensures good material distribution throughout the product. The trophy follows this rule from the base all the way to the figurine so that the blown material can reach all the way down into all parts of the mold. This can be seen in Appendix I as Figures 3 and 4. There are several other factors that determine whether your material can fill your mold correctly without defect.

One of these factors to take into consideration are sharp corners and edges. With sharp corners and edges, the blown material can become thin and blow out as it tries to expand into these tough to reach spots. To combat this issue, the sidewall angle can be changed to create a less dramatic and rounded corner. Common sidewall angle shapes include a rounded radius angle or a chamfer angle, which can be seen in Figure 5 [3]. Key spots on the trophy to use these angle types are on the base and on certain types of figurines like the star to ensure a successful molding process.

In a successful molding process it is integral to be able to remove your blown product from the mold with ease. Factors such as the draft angle and shrinkage of the product influence the removal of the part from the mold. The draft angle for the sidewalls of your mold contribute greatly to this removal. A draft angle that creates back draft will hinder the removal of your product while a positive draft angle will ease removal. The trophy has no spots which will cause back draft which means removal should not be an issue.

In addition, shrinkage must also be considered for the removal of a blown part. Any spots which have shrinkage toward the mold walls rather than away from will cause trouble when removing the part. These points of shrinkage toward the wall can happen when we have a part which wraps around a section of the mold like in Figure 7 [15]. With the trophy there are no spots with this specific type of shrinkage. Although shrinkage does not cause a problem in the removal of the blown product, it is still important to control and minimize shrinking so that the part is produced as planned. A larger wall thickness will shrink more than a thinner wall. For this reason, a wall thickness of 0.125” was chosen to prevent shrinkage more than 2%. A uniform wall thickness can be ensured throughout the product by using parison programming to influence the parison wall thickness. By creating a
parison with thicker walls for the parts with sharp corners and edges it can be ensured that there is no excessive thinning as the material is blown into these corners. By controlling the shrinkage and wall thickness the chance of warpage and defects decreases.

![Mould cavity](image)

**FIGURE 7:** Shrinkage of blow molded material onto the mold (Courtesy of Practical Guide to Blow Molding)

**MATERIAL JUSTIFICATION AND PROCESSING**

Polypropylene is one of the most common plastics used in blow molding. Polypropylene is widely used in engineering and manufacturing because of its high strength, flexibility and resistance to fatigue. In addition, polypropylene is used because of its high melting point and its chemical resistance to organic solvents. For the purpose of blow molding trophies, polypropylene was chosen because of its high stiffness, high rigidity, and the low cost. However, polypropylene is a polyolefin which means that polypropylene is hydrophobic and is not suitable for paints and adhesives. To combat this, after the blow molding process the trophies will undergo flame treatment to increase the surface energy and improve the adhesive properties. Since it is necessary for the trophies to be able to hold adhesive or paint, it must be flame treated. Before flame treatment, the polypropylene surface is made of only carbon and hydrogen chains. Flame treatment will cause the oxidation of methyl groups into hydroxy groups which will improve the adhesion of paints and adhesives due to stronger intermolecular forces between the surface and the paints or adhesives.

**MOLD AND TOOLING DETAILS**

The main feature of the mold design will be a system to allow a customizability of the mold depending on what a customer wants. By creating a standard size for a pan to hold the mold, the manufacturer can develop parts of a mold that when put together will make up the entire trophy. Different figurine molds can be made, along with different column and base patterns. These parts will be interchangeable with one another so the customer can choose a customizable trophy to develop from the mold shapes available. After receiving a custom trophy order, the manufacturer would create a mold in the standard size pan. This would be done by placing interchangeable parts into the pan. Each interchangeable part would only represent half of a feature (figurine, column, tier, etc.) and the entire mold, once all interchangeable parts had been placed, would only represent half of the whole mold for the trophy design ordered. The manufacturer would then create a symmetrical half-mold in the same fashion mentioned before, yielding a full mold for the trophy.

![Half mold design drawing](image)

**FIGURE 8:** Half mold design drawing (dashes represent sections for interchangeable parts)

When developing a mold design, it is important to be able to create a consistent and
uniform product through every cycle that is run. There are several factors that must be controlled or thought about when designing the mold.

One important feature of creating a mold is to develop a cooling pattern to ensure effective cooling per cycle and to ensure a uniform cooling of the blown part. If the cooling is not sufficient, there will be an increase in temperature of the mold for each cycle. This will cause inconsistent cooling between cycles and can cause an incorrectly blown part. In addition, a non-uniform cooling can result in warpage of the final product. In addition, by increasing the rate of heat transfer one can cut down on cycle time and have a higher rate of production.

There are two points of heat transfer in the blow molding process. The first is the heat from the plastic melt flowing into the mold. A material with a high thermal conductivity will work best for this application to ensure that the mold can act as a heat sink. The second point of heat transfer is the heat from the steel mold into the cooling fluid. To ensure sufficient cooling, a well-designed cooling channel specific to the blow molded part is needed.

Many factors go into designing the cooling channel for a mold. The cooling channel in a mold passes liquid through a mold in order to transfer heat from the mold into the liquid in the channel. It's important to design your mold and cooling channels to ensure that enough heat is dissipated. For our part, with a wall thickness of 0.125 in, a cooling channel diameter of 0.394 in. will be sufficient. Another important factor to consider is how the liquid will flow through the channels. The coolant can have either laminar flow or turbulent flow depending on the velocity. Laminar flow is when a liquid flows smoothly and in layers where turbulent flow has agitation which is caused by its higher velocity. For heat transfer, turbulent flow removes a greater amount of heat than laminar flow because of the agitation. The overall layout of the cooling channels is something that needs to be taken into consideration as well. A good layout will focus the channels on those parts with higher wall thickness. Since the proposed design will have the same general wall thickness throughout, an evenly balanced design will be used much like the one in Figure 9 [3]. If one large channel was used, the coolant will warm up as it moves through and will not remove as much heat in other parts of the mold. The design in the figure allows for many inlets and outlets which will help keep the heat transfer into the cooling channel consistent and will decrease the chance for warpage or inconsistent products.

Venting is another important factor to ensure the part is blown as intended. When a parison is captured by the mold, there will be some amount of air trapped between the outside of the parison and the mold walls. Without venting, this trapped air will cause defects in the blown part. Improper venting has a large effect on the overall appearance of a blown part. Vents should be placed as frequently as possible to prevent any problems that can arise from trapped air in a mold. In addition, care must be taken to have the vents be large enough to allow gases out but small enough to ensure that plastic cannot flow out.

**FIGURE 9:** Cooling channel layout (Courtesy of Custom-Pak Design and Blow Molding)

**MANUFACTURING DETAILS**

Blow Molding is a method of manufacturing hollow plastic parts which involves the use of placing a heated plastic parison or preform into a mold and blowing air into it in order to inflate it into the shape of a cold mold. There are two main types
of blow molding: Extrusion blow molding and Injection Stretch Blow molding. For blow molding trophies, extrusion blow molding was chosen because of its advantage of being able to mold complex parts over the injection stretch blow molding. In blow molding a trophy, there are places that have sharp corners and some complex shapes so the ability to get these shapes is important.

In stretch blow molding, a preform is used. This preform is a small plastic tube which usually has the neck of the bottle containing the threads. The preform is heated and placed inside of a mold where air is injected into the preform to take the shape of the mold.

For Extrusion Blow Molding, the process first starts with combining your raw materials into a blender. The blender mixes all of the raw materials to ensure a homogenous mixture. This mixture is fed from a hopper into a horizontal extruder which contains a reciprocating screw. In this barrel, the plastic is heated to the appropriate temperature to melt and the reciprocating screw pushes the plastic forward. As the screw pushes the plastic, additional heating is applied by a narrowing of the barrel and the turning of the screw which causes friction and shear heat. At this point in the process, the plastic is well mixed, at the appropriate temperature, and is referred to as a plastic melt. The plastic melt is then extruded into the die head around a mandrel. There are two main types of die heads: a radial flowing die head and an axial flowing die head.

In a radial flowing die head, the plastic melt comes in horizontally to the die head. The flow is then split around the mandrel and recombines on the other side. In an axial die head, the plastic melt comes in from above and flows around the head of a torpedo and down around the mandrel. An axial die head has two main advantages over the radial die head. In the radial die head, there is a difference in flow rate in the die head. This is because of a pressure difference created by the recombination of the two flows on the other side of the mandrel. In addition, the place where the two flows recombine can be a weak spot if extra care isn't taken to be sure they align properly. For these reasons, an axial die head was chosen. Once the plastic goes around the mandrel or torpedo, the plastic melt is in the shape of a melted plastic hollow tube called a parison. It's very important to be able to control the wall thickness of your parison when designing your manufacturing process.

One thing that affects wall thickness is die swell. Die swell refers to the swelling of a polymer after it has been forcefully put through a die. After the polymer leaves the die head as a parison, it is common for the polymer to relax or swell which can make controlling the wall thickness difficult. This can be compensated for by increasing the length of the die and lowering the flow rate. Another factor which influences the wall thickness and uniformity of the parison is the speed of extrusion. There are two different methods of extrusion processes: intermittent or continuous. The method chosen affects the speed of parison formation.

In an intermittent process, plastic melt flows into an accumulator. After enough plastic is gathered in the accumulator, it's pushed around the mandrel to form the parison. There is a barrel accumulator, where material is accumulated in the barrel; there is also a die head accumulator where material is gathered in the die head. In a continuous process, the screw in the barrel is constantly pushing plastic melt through to create a continuous parison. The main difference of the two has to do with a uniform wall thickness. In a continuous process, there is a chance of sagging and thinning near the top as the parison spends a longer amount of time being formed. For an intermittent process, plastic melt is pushed quickly which results in a uniform parison. Deciding between which method to use depends on the melt strength of your polymer being used.

Melt strength refers to the resistance of a polymer melt to stretching. A low polymer strength means that a parison is more likely to sag. A low
melt strength can be compensated by using intermittent extrusion while a high melt strength allows for the use of a continuous process. For this specific process, a continuous process will work. The part being blow molded is relatively small so sagging won’t be a large issue. Even so, the top of the trophy, which will have the most complex parts, will be in the bottom of the mold so having a greater thickness at the bottom of the parison may be beneficial to ensure there is no excessive thinning or blowout as the parison is blown into sharp corners. However, if sagging is an issue, it can be improved upon by regulating the temperature of the plastic melt. By ensuring that the plastic melt is just above the melting point of the polymer, you can improve the melt strength and decrease sag. In addition, wall thickness can be better controlled through the use of parison programming. Parison programming allows one to change the thickness of the parison as it comes out by moving the mandrel or bushing of the die head up and down. This essentially widens or shrinks the gap which the parison flows through. Once the parison flows out, a cold mold is clamped around the parison and pinches it closed at the bottom. The mold and parison are moved aside so that air can be injected to form the part, a trophy in our process. The trophy is removed from the mold and completes the blow molding process.

FINISHING

Once the trophy is removed from the mold, it moves on to further manufacturing processes to be ready for sale and use. Excess plastic is removed from the trophy, and the final shape of the trophy is achieved after some trimming. Depending on the shape, and type of trophy, different amounts of trimming will be required.

For the single column trophy, trimming would mainly be needed for the base to remove the point of air insertion. With the double column trophy, a more extensive trimming process will be needed in order to remove the middle piece of plastic between the trophy columns.

The trophy then can be sent for detailing and painting. Polypropylene is not usually suited for paints and adhesives. To combat this, part of the finishing process will be to flame treat the trophy in order to improve the surface properties. Adhesives and paint can then be applied to achieve a more finished, nicer trophy look. Metallic foil can be added to the trophy, much like it is done currently, and the separate parts of the trophy can be painted (either by hand or otherwise).

The final step of the finishing process is to attach the trophy to a base and add any plaques that are requested. The blow molding process allows for flexibility with the base design. If the design order calls for a marble base, the plastic can be blow molded and trimmed so that a marble base can be added. This can be done in several ways depending on how the customer wants their final trophy to look. The marble base could be screwed on and the screws can then be covered with a variety of small figurines to keep the look of the trophy refined. Another method is the use of adhesives to attach the rest of the trophy to the base. A marble base also doesn't have to be used depending on what the customer wants. A plastic base can also be used and attached.

FIGURE 10: Blow molded double column trophy after trimming
using the same methods as a marble base. Once the rest of the trophy is attached to the base, plaques can be added if desired to complete the final trophy which is now ready for sale and use.

**COST ANALYSIS**

Consultations with multiple trophy design companies (Trophy Depot, Dinn Trophy, Crown Awards, etc.) yielded the following:

- For an order of 100 of the single column trophy in a 12 inch size and a similar design to the model previously established, the average price would be $7.73/ea [8] [18].
- For an order of 50 of the double column trophies at a 20 inch height and a similar design to the model previously established, the average price would be $21.58/ea.

This means that an organization ordering 100 of the single column trophies would pay an average of $773.33 plus shipping and tax on an order, and would pay $1,078.75 plus shipping and tax on an order of 50 double column trophies.

The proposed blow molding design aims to reduce the cost of these orders, since the trophies would no longer need to be hand assembled once they are blow molded, eliminating a significant amount of labor cost. Some human labor would still be necessary for trimming and finishing, but the amount would be marginal compared to the amount needed to assemble the same amount of trophies by hand.

Once blow molded using polypropylene, the single column trophy would weigh approximately 0.136 kg (0.30 lbs). At a price of $932/metric ton [24], the material alone for the production of one single column trophy would cost $0.13. As labor and shipping can vary in cost depending on the location of the blow molder, it can be safely assumed that they would not escalate the cost of producing a trophy by a significant amount. This was confirmed by a Blow Molding Cost Analysis conducted by Norland International, which estimated the labor cost as 5% of the material cost. The same approach was used to estimate the cost of electricity which yielded a cost value 10% of the material cost [6]. Profit margins vary with each company but, using an assumption that small businesses have a profit margin of 14.56%, a retail price can be estimated [13].

The double column trophy would weigh an estimated .494 kg (1.09 lbs). Using the same raw material cost for polypropylene, the material in one double column trophy would cost $0.46. The table below shows the full breakdown of estimated costs for the two blow molded trophy designs.

<table>
<thead>
<tr>
<th></th>
<th>Single Column Trophy</th>
<th>Double Column Trophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene Cost</td>
<td>$0.13</td>
<td>$0.46</td>
</tr>
<tr>
<td>Cost of Base</td>
<td>$1.80</td>
<td>$2.58</td>
</tr>
<tr>
<td>Cost of Labor (Est. $6.00/hour)</td>
<td>$0.0065</td>
<td>$0.023</td>
</tr>
<tr>
<td>Cost of Electricity (Est. $0.20/KWH)</td>
<td>$0.013</td>
<td>$0.046</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$1.95</strong></td>
<td><strong>$3.11</strong></td>
</tr>
<tr>
<td>Profit (14.56%)</td>
<td>$0.2839</td>
<td>$0.4528</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$2.23</strong></td>
<td><strong>$3.56</strong></td>
</tr>
</tbody>
</table>

Therefore, an organization ordering 100 single column trophies would save an estimated $550.33 (71.2%), and $900.75 (83.5%) on an order of 50 double column trophies!

**CONCLUSION**

The designed trophy serves as a more cost effective and more easily produced version over its handmade counterparts. By changing the manufacturing process of handmade trophies to a
continuous extrusion blow molding process, trophies can be made with a faster cycle time for less cost.

Polypropylene as a material provides a rigid and strong feel to the trophy. It is a commonly used blow molding material because of its low cost, strength, and durability. Although flame treatment is needed polypropylene is a good candidate material.

By allowing for interchangeable parts in the mold, the customer has a degree of customizability to create the trophy for their needs. In addition, the design of the base of the trophy will determine what kind of trimming and finishing will be needed.
Appendix I

FIGURE 3: Double column trophy drawing sheet

FIGURE 4: Single column trophy drawing sheet
REFERENCES


