Hard Shelled ABS Extrusion Blown Suitcase

Kristen Kilroy
Pennsylvania State University – Behrend
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Introduction

A large industry in today’s life is travel. Whether it be vacations, business trips, or just visiting friends and relatives, today’s society is no longer based around staying put. Traveling brings the need for luggage, which is necessary to protect anything that may need taken with on the trip. Suitcases are generally made of fabric, but there is a growing plastic suitcase market, due to the customer’s desire to protect their possessions. These plastic suitcases, though durable, can be expensive. This is due to the way they are made.

Application of Blow Molding

Hard-shelled plastic suitcases are able to withstand normal use while creating a hard enclosure around the user’s belongings. Currently, these suitcases are being made by means of injection molding processes.

If these bags were created using extrusion blow molding, there is a possibility of the price of them to be decreased. This is due to a number of factors.

For instance, in injection molding, there is no feasible way to create a large, hollow part. Injection molding these parts would require the mold to either contain multiple cavities, making it extremely large, or running another cycle. The main advantage of extrusion blow molding is its ability to create large parts that are hollow. This allows both sides of the suitcase to be created at once. Figure 1 shows a modeled representation of how the suitcase would look if it were to be extrusion blow molded.

![Figure 1: Suitcase interpretation modeled in ProEngineer](image)

Another example of cost reduction would be the fact that molds in extrusion blow molding to be created using aluminum, which is much easier to machine than the steel used in injection molding.

One final advantage of using extrusion blow molding to create hard-plastic suitcases is that it is possible to co-extrude recycled materials to reduce the cost of material. Though injection molding can also do this, extrusion blow molding can incorporate the savings of material costs with the other cost reductions mentioned and produce cheaper parts overall.

Extrusion blow molded parts can only contain detail on the exterior, where the polymer touches the mold. Suitcases usually contain an interior fabric casing in which appeals visually to the consumer. This lack of surface finish on the interior therefore does not affect the final product of the suitcase because of the interior fabric casing covering it.

Design Details

The improved blow molded product can be molded from ABS or polypropylene materials, both of which are currently being used for in the injection molding of the suitcases, but ABS seems to be the better candidate. ABS is an amorphous material with very good impact strength that is commonly used to create housings for many different products. It has superior mechanical properties compared to polypropylene, in addition to having a higher heat deflection temperature, allowing it to survive an automobile on a hot summer day better. The amorphous nature of the material also benefits the design. Amorphous materials tend to shrink less than a semi-crystalline material, which leads to more repeatable parts.

The current part is made using a polypropylene material that is a very cheap, highly impact-resistant plastic that is strong, lightweight, flexible, and moisture resistant. Polypropylene is one material being used today for applications such as these hard-case suitcases, automotive industries, and it also has some applications in the food industry due to it meeting FDA requirements. Polypropylene, however, has a heat deflection temperature of seventy degrees Celsius, which is much lower than the proposed ABS material. This low heat deflection temperature will cause the material to become very weak and easily deformed in a hot environment. A part made of this material will also not be able to withstand the forces that a part made of the ABS material will be able to withstand because of the lower mechanical properties.

The suitcase could see relatively high heats but under little stress. The highest temperatures that the suitcase would see in average use would be a car...
trunk on a hot day where temperatures could reach upwards of 70° C. The most stress that could be applied during this extreme could be caused by the weight of another suitcase resting on top of the product. The published heat deflection temperature, or temperature that the material deflects under a 1.8 MPa load, is 88° C. This translates to acceptable performance of the product. These temperatures are also extremes. Temperature exposures can range from 10° C to 60° C. It would have to withstand hot temperatures, such as from sitting in a car on a hot day. This suitcase would also have to withstand cold temperatures, such as when placed in the luggage compartment of an airplane. ABS has the ability to withstand temperatures as low as -20° C.

The only chemicals that suitcases may come in contact with are oils, salts, water, and maybe gasoline, all of which ABS can withstand.

The costs of ABS are currently about $2.64 per kilogram of material. Polypropylene is priced around $2.71 per kilogram of material.

The suitcase designed was constructed with the dimensions of 914.4 mm. X 609.6 mm. X 304.8 mm. The mold shown in Figure 2 is just a basic interpretation. This model represents a large suitcase. The mold side walls contain a draft of 2 degrees, which will aid in the ejection of the part.

![Figure 2: Half of the mold. (Right) The mold with the part shown inside.](image)

The blow ratio for this part has been determined to be 3.15:1, given the parison diameter to be 193.4 mm. and the width of the part to be 609.6 millimeters.

In order to analyze the effectiveness of this design achieved through blow molding as opposed to injection molding, a finite element analysis (FEA) simulation was completed for the design. A FEA analysis is a solution method essential for calculating stresses in complex geometries. It is often used to optimize a design to increase strength, increase rigidity, and save material.

The FEA analysis program used in this experiment is ANSYS Workbench. A three dimensional model of the part is created in ProEngineer Wildfire. From there, the part is assigned a mesh. By assigning the correct material properties to the part, it becomes possible to calculate failure loads and deformations, in addition to many other variables that the part will see in its use. It should be noted that FEA does not account for orientation effects which are created when plastic material flows.

The first step of the design procedure was to model the full suitcase in ProEngineer. The model of the part was then shelled to a thickness of 3.175 mm, and cut in half to take advantage of symmetry in order to simplify the model. A mesh sizing of 6.35 mm was used for each analysis.

The data properties for the materials to be used were entered into the Engineering Data of ANSYS Workbench. The specifications of the materials used can be seen in Figure 3.

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s Modulus (MPa)</th>
<th>Density (g/cm³)</th>
<th>Tensile Yield Strength (MPa)</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>2551</td>
<td>1.04</td>
<td>43</td>
<td>0.4</td>
</tr>
<tr>
<td>PP</td>
<td>1379</td>
<td>0.9</td>
<td>27.6</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Figure 3: Shows the properties of the materials used

Before running the analysis, the boundary conditions for each analysis were set. The first analysis simulated a load of 445 N on the bottom, inside surface of the suitcase while being held where the handle of the suitcase would be. It should be noted that 445 N is half of the load called for in the design specifications, which is because the model used for the analysis only represents half of the suitcase for simplicity. The Boundary Conditions Plot used can be seen in Figure 4.

![Figure 4: Boundary Conditions plot simulating a load of 90 kg being supported on the inside of the suitcase](image)

The second analysis simulated a load of 556 N pushing inward, onto the outer surface of the suitcase.
to simulate the force of a person sitting on the suitcase or other luggage piled on top of the suitcase. It should be noted that 556 N is half of the load called for in the design specifications, which is because the model used for the analysis only represents half of the suitcase for simplicity. The Boundary Conditions Plot used for this analysis can be seen in Figure 5.

The third analysis simulated a load of 556 N pushing inward onto a different outer surface of the suitcase to simulate the force of a person sitting on the suitcase or other luggage piled on top of the suitcase. It should be noted that 556 N is half of the load called for in the design specifications, which is because the model used for the analysis only represents half of the suitcase for simplicity. The Boundary Conditions Plot used for this analysis can be seen in Figure 6.

The fourth analysis simulated a load of 1112 N pushing inward, onto the largest outer surface of the suitcase to simulate the force of a person sitting on the suitcase or other luggage piled on top of the suitcase. The Boundary Conditions Plot used for this analysis can be seen in Figure 7.

Figure 7: Boundary Conditions plot simulating a load of 113 kg being supported on an outside surface of the suitcase

After boundary conditions for each plot was established, the analyses were run. Once finished, the results were collected and analyzed.

The purpose of the analyses performed for this study was to see if this design meets the design specifications indicated. The following plots show the results of the analyses performed for the ABS material.

Figure 8 shows the Maximum Principal Stress Plot for the loading case simulating a 90 kg load on the inside of the suitcase. The maximum principal stress with these loading conditions is 22.5 MPa, which is under the tensile yield strength for this material. This means that the material did not yield under these conditions and can safely support 90 kg. The deflection was also analyzed, and found that the total deflection was 9.8 mm.

Figure 8: Maximum Principal Stress Plot for the loading case simulating a 90 kg load on the inside of the suitcase

Figure 9: Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the largest outside of the suitcase.
Figure 9 shows the Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the largest outside surface of the suitcase. The maximum principal stress with these loading conditions is 8.9 MPa, which is well under the tensile yield strength for the ABS material. This means that the material did not yield under these conditions and can safely support 113 kg. This analysis also showed that the maximum the plot deflected was 12.9 mm.

Figure 10: Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the lengthwise outside of the suitcase

Figure 10 shows the Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the lengthwise outside surface of the suitcase. The maximum principal stress with these loading conditions is 27.0 MPa, which is under the tensile yield strength for the ABS material. This means that the material did not yield under these conditions and can safely support 113 kg. This analysis also showed that the maximum the plot deflected was 16.4 mm.

Figure 11: Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the widthwise outside of the suitcase

Figure 11 shows the Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the width-wise outside surface of the suitcase. The maximum principal stress with these loading conditions is 10.1 MPa, which is well under the tensile yield strength for the ABS material. This means that the material did not yield under these conditions and can safely support 113 kg. This analysis also showed that the maximum the plot deflected was 15.2 mm.

The following plots show the results of the analyses performed for the suitcase being made from PP material.

Figure 12: Maximum Principal Stress Plot for the loading case simulating a 90 kg load on the inside of the suitcase made of PP

Figure 12 shows the Maximum Principal Stress Plot for the loading case simulating a 90 kg load on the inside of the suitcase. The maximum principal stress with these loading conditions is 20.9 MPa, which is under the tensile yield strength for the PP material. This means that the material did not yield under these conditions and can safely support 113 kg. This analysis also showed that the maximum the plot deflected was 18 mm.

Figure 13: Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the largest outside of the PP suitcase

Figure 13 shows the Maximum Principal Stress Plot for the loading case simulating a 113 kg load on the largest outside surface of the suitcase. The maximum principal stress with these loading conditions is 8.9 MPa, which is well under the tensile yield strength for the PP material. This means that the material did not yield under these conditions and
can safely support 113 kg. This analysis also showed that the maximum the plot deflected was 23.9 mm.

Overall, these analyses proved that the ABS material would be a better choice than the PP material. Since the tensile yield strength for ABS is higher than that of PP, it is much less likely to yield. The ABS suitcase met all design specifications while the PP suitcase failed one of the four design specifications. Also, it should be noted that in every case, the PP material deflected significantly more in each analysis due to the fact that the ABS material has a higher Young’s Modulus. This would cause problems with a fully assembled suitcase, since high deflections could cause the hinges or other components to fail.

Mold & Tooling Details

For the creation of a typical suitcase, an extrusion blow molding machine would be required. This machine would need to have a diverging head die due to the large diameter of the parison.

Secondary operations would also be required. This would include a trimming station and an assembly station.

Manufacturing Details

This suitcase will use two blow needles, one located on the top left, the other on the top right of the part. This will facilitate the blowing of the parison against the mold walls.

The pinch off is not an issue with this design because the part will be cut in half anyway, meaning the weld line does not have to be strong.

There will need to be plenty of venting inside this mold due to the size of the part.

Acknowledgements

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Thickness of Mold (both halves): 381 mm

Thickness of Part: 304.8 mm