Blow Molding Part Design

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Suit or Garment Box

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Abstract

A two-part Extrusion Blow Molded suit case was designed to house and protect expensive clothing such as suits or tuxedos. The design is chemical resistant, structurally acceptable, and the final design would be waterproof. The purpose of the design is to provide more protection during storage or transport than typically used garment bags. Particular attention was directed towards minimizing secondary assembly operations by incorporating a hinge and snap fit into the part design. Design modifications were made using CAE programs to reduce the weight of the parts by 11%. The specifications were met through material selection and part design, and then further improved through use of CAE.

Introduction

This report will review the specific design goals and specifications that are intended for this product. It will also walk through the design process and evolution of the part from the original sketch to the revised Computer Aided Design (CAD) models of the final design.

The primary goal of the product is to protect its contents from being damaged. Typically used garment bags are often made of cloth and do not offer the best protection. As suits and tuxedos can easily be priced over $1,000 a piece, investing in a protective storage box is a practical purchase for anyone. The design is meant to last at least ten years and requires no secondary operations besides removal of flash.

After developing a product idea, part of the challenge in designing this part applying a mechanism to hinge and secure the top and the bottom halves. The part design incorporates a design with a hinge that has a top and bottom half molded into each part of the case. The design includes a Blow Molded handle so that the case can be easily transported if desired. The snap fit that holds the case closed is part of the handle, which is molded in two halves on each side of the mold. The design will be further discussed in the Presentation of Design section, which will also illustrate the design process.

This part design incorporates a design with a hinge that has a top and bottom half molded into each part of the case. The design includes a Blow Molded handle, so the case can be easily transported if desired. The snap fit that holds the case closed, is part of the handle, which is molded in two halves on each side of the mold.

Computer-Aided-Engineering (CAE) programs were used during the part design process as well as for improvement of the design. The parts and Blow Mold were modeled using Pro/Engineer Wildfire 5.0 and design improvements were made after performing Finite Element Analysis (FEA) using ANSYS Workbench.

Statement of Theory and Definitions

There are uncountable products on the market that are specifically designed to protect clothing. These products are usually made from a flexible polyester or cloth material. Garment bags on the market range can range in price anywhere from $40-$750. Although these have the benefit of being able to be rolled up or folded, they do not serve as rigid protection for its contents and are not usually waterproof or chemical resistant.

The design goals and specifications are as follows: (1.) Chemical Resistance (2.) Ergonomic Open/Close Mechanism (3.) Structurally support three cases stacked on top surface (4.) Handle capable of supporting twice the weight of the parts when assembled and disassembled. (5.) Weight must remain below 10 kg. (6.) Ten-year service life

Material selection plays a critical role in the product development process and there are many variables to consider when selecting a material. First of all, the product could be exposed to a wide variety of chemicals depending upon where it will be stored.
If the consumer wants to store it in a garage, it will need chemical resistance to gasoline and other automotive chemicals.

High Molecular Weight High Density Polyethylene (HDPE) was chosen for this application for its excellent chemical resistance, recyclability, and toughness. A high molecular weight grade was chosen in order to gain additional impact strength. HDPE is flexible material, and was best suiting for the flexibility the handle required for the snap-fit. HDPE was the initially proposed material, however; ABS was considered as an option but there were concerns regarding its high modulus and poor chemical resistance. HDPE also has a low Glass Transition Temperature and will not be brittle when traveling or storing the product in cold temperatures.

Snap fitting features are features that are used very often with plastic parts. A snap fit feature will deflect during assembly and return to a relaxed state internal to the assembly. It is important that the part is not under stress during assembly, because plastic materials have viscoelastic properties. The material will flow and permanently deform if held under a constant load or constant strain.

Snap fits provide a mechanical mean of assembly without use of fasteners such as rivets, pressed-in inserts, screws, or bolts. This is an advantage for many different reasons, all of which could pertain to this application. First of all, the costs of assembly are essentially eliminated because it will not require labor, or purchase of fasteners. After the product is done being used in this application, the absence of mechanical fasters will allow it to be easily recycled.

Blow Molding is a process that is used to produce hollow parts. To simply define any blow molding process, air is pressurized within a semi-molten layer of plastic which is surrounded by a mold. The air pressure stretches and expands the softened plastic outward until it contacts the walls of the part forming cavity of the mold, which cools and solidifies the part. The process is illustrated in Figure-1.

The original concept for the design was to mold the entire shell for the case in a single mold, then cut apart the sections. This would have required secondary operations to assemble hinges and latches. This idea was thrown out for economical concerns regarding the cost and difficulty of assembly. It also would have compromised appearance along the edges of the part where it was cut as well as structure of the part with a thin, single wall.

The wall thickness of the Blow Molded part will have a direct effect on the weight, flexibility, and loading capabilities of the part. With the specifications set, the only way of determining the proper wall thickness is through testing and prototyping.

CAE programs are an important part of the design process. They allow simulations and prototyping to test products before they are actually made. This is particularly an advantage with plastic parts because the initial cost of a part is very high. A finalized product is not made until a mold is build and a machine is running parts.

Pro/Engineer is a 3D CAD program. There are many different CAD programs available but each provides the same basic features. By using a large variety of 3D modeling commands, users can model any imaginable shape or design. The model can then be saved in a compatible format for simulation software such as FEA. A skilled user will model parts in a fashion that allows quick and easy modification of critical dimensions and features.

FEA is a CAE program that if used properly, allows users to accurately measure stresses a part may potentially experience in an application. For a 3D part, the program will create a mesh using elements and nodes, much like Moldflow Simulation Software. At each node, the analysis will perform the desired calculations along three degrees of freedom. The shape and size of the mesh can be critical to the analysis. For example, a smaller mesh size is often used in corners and along fillets or rounds. The smaller mesh size will more provide more accurate data in those locations, which are known as areas of stress concentration. The size of the mesh will also have an effect on the amount of time and memory the analysis will require to run. Geometry that is
unnecessary should be removed and if possible, models should be simplified cutting the model along planes of symmetry. As long as the loading is symmetric, symmetric portions of a model will have a mirror image of stress evaluation. In this case, the entire model can be analyzed by observing half of the model.

Boundary conditions are another critical input when performing FEA analysis. Boundary conditions are the constraints and forces that are applied to a part prior to analyses. It is important to apply appropriate conditions in order to obtain data that will be relative to the application.

A factor of safety is often included in the design of a part. Material properties can vary greatly, and material data sheets do not always provide data that was tested under identical conditions. A factor of safety helps account for the variation in material properties and ensures that the part will not fail over time. It can also account for the fact that it is likely that someone will use a product in a way it was not intended or designed for.

**Design Validation**

Each of the five design goals and specifications were validated through practical terms such as research or CAE. This section will provide details on the analyses that were performed.

Chemical resistance was a matter of material selection. Semi-crystalline materials generally have good chemical resistance and HDPE was chosen for its chemical resistance to a broad range of substances. A material data sheet for High Molecular Weight HDPE is attached in the appendix.

The mechanics of the snap-fitting handle and integrity of the structure of the box will be proven by FEA using ANSYS. Mesh refinements were applied in critical areas with stress concentrations. If the applied stress does not exceed the yield stress of HDPE (25 MPa) then the part will not fail based on the equivalent stress theory. A factor of safety of at least 2.0 at each specified loading condition is preferred for the design to help defend the design goal of a 10-year service period. If a part is designed with a high factor of safety, it is less likely the part will fail.

FEA analyses were run with the goal of answering the following questions, which are directly related to the design goals that were discussed: (1.) How much weight can be stacked on top of the part? (2.) How much force must be applied in order to release the snap fit? (3.) How much force can be held by the weaker half of the handle when assembled? (4.) When disassembled? Tables 1-4 show the mesh statistics that were used when each situation was simulated. The table numbers match the conditions discussed above.

### Table 1: Stack Strength (1)

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### Table 2: Handle Unassembled (2 and 4)

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### Table 3: Handle Assembled (3)

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Pro/Engineer will be used to determine the volume of the parts, and by multiplying the volume of the parts by the density of HDPE (9.5×10^{-7} kg/mm^3), the weight will be calculated. The material cost information was researched on “plasticsnews.com”, which provides current prices for many plastic materials. Figures 5 and 6 show the CAD analysis of solid volume (kg/mm^3) for the original and revised parts.
Mold/Tooling

The design would require two separate molds for each of the parts. The molds would need compression pinch-offs around the perimeter of the parts as well as for the internal cuts such as the hole in the handle for the bottom part. The top part would require a mold with a stepped parting line. The parting line would be stepped to create the snap handle for the top side, which extends lower than the main edge of the part. The reason the part is designed this way, was to enable the snapping handle to extend below the handle of the bottom side. An ovoidal diverging die and mandrel would be used for the part. The diverging die is more suitable for this large industrial part.

Design Procedure

The first step in designing the Blow-Molded suit box was to develop concepts by making sketches. The initial sketch of the part is shown in Figure-2. The idea was a start for the process but was simplified to fit the needs of a Blow Molding application.

Next, a finalized concept was decided upon and CAD models were created using Pro-Engineer. The location of the handle and hinges were critical to the design. The spacing of the hinge supports had to allow the top to slide at least 228.6 mm (width of handle) in order to release from the snap fit. Figure 4 shows the critical dimensions of the handle and hinge supports as well as a cross section of the snap fit handle. The bottom half of the handle is part of top cover of the box. The models were developed using skeleton models, which is a method of creating top-down assemblies and allows drastic design changes to be made at the assembly level. The part files affected by the change will automatically update. Figure 5 and 6 display cross sections of the original and revised design. The original volumes of the designs are shown in Figures 1 and 2, which by the density of HDPE are equivalent to 10.4 kg and 9.3 kg. The weight reduction put the part below the maximum weight specification for the design. It also greatly reduced the length that core would have to draw into the cavity side of the mold to for the
The original and revised designs have the same wall thickness of 2.54mm. The analyses on ANSYS showed that this wall thickness was sufficient to achieve the design goals that were listed at the beginning of the report. The design was then changed to reduce weight more to further improve the factors of safety. For each analysis, one unit of force was applied to the part. In a linear analysis, the stress will be proportional to the load. A ductile material will fail at the material's yield strength (25 MPA) causing permanent deformation. The ANSYS plots shown are for the revised part and will show the boundary conditions that were applied and a plot of the stress at the target load requirement.

Figure 7

Figure 9 shows the boundary conditions that were used to simulate the effect of stacking the parts. Half symmetry was used to reduce the size of the model, therefore applied load would be double in the whole model to achieve the same stress. A distributed load was applied at the top surface at targeted load value at three times the weight of entire assembly (137 N) was applied. The resulting stress in the part was 11.95 MPA, a factor of safety of 2.09.
Figure 8

Figure 8 shows the analysis that was performed to test the required force that must be applied to the handle to allow the snap fit to release. A 31.38N force was applied to the chamfered surface of the handle, which deflected the top surface of the snap fit 10.559mm. This deflection is greater than the required 10.16mm deflection for release. The stress at this load was 17.6 MPA and is a factor of safety of 1.4.

Figure 9

The analysis conditions shown in Figure 9 are for simulating the effect of holding the handle for the top part when it is not assembled, which was targeted to hold twice the weight of the part (2x 42.258 N). The half of the handle that will experience the most stress is the half that is only attached by one side of the handle (top half of part), so it is the only side that was analyzed. A frictionless support was applied where the handle was cut from the rest of the part, the material will act as if it is still connected to the part. At the applied load (84.516N), the part experienced a stress of 11.735 MPA, a safety factor of 2.13.
The simulation shown in Figure 10 is much like the simulation shown in Figure 9, except this analysis includes a compression only support on the top of the snap fit, which simulates the surface mating with the surface cut into the other side of the handle during assembly. In table three, it can be seen that this analysis had more elements than the previous one. This is because the mesh was refined around the area of the snap fit. At the applied load, twice the weight of the assembly (18.6 kg/182.6 N), the stress in part was 12.643 MPa, a factor of safety of 1.98.

Conclusions:

The design of the part was proven to meet all of the design specifications. The loading conditions applied were appropriate for the situations that the actual part will experience.

The stack force analysis proved that one box would be capable of stacking three others on top of it. The distributed loading case was appropriate because the weight will be distributed along the bottom of each of the boxes. The top surface would yield when seven boxes were stacked or at 572.68N. This is meant to simulate a storage condition in which multiple boxes were stacked to save space. An issue with this is that plastic materials will creep over time and if the parts were stacked for a long period of time the parts will permanently deform.

The simulation showed that the snap fit would be easily removed after assembly. A load of 31.14N will deflect the handle so that the top surface of the snap can be released from the mating side of the handle. For this to occur, the deflection had to be greater than 10.16 mm. This simulation proves that the assembly will be easy to disassemble, but the stress would be significant enough remain joined. The snap fit is design with a flat surface on the side that it would be drawn to release. This is a “one-way” type snap fit and the only way it can release is by applying a force great enough to deflect the surface below the interfering female side, and then pulling the top half downward. The design is safe because in order to apply the downward load to release the snap fit the load must be applied the chamfered surface of the handle, which is protected from accidental release by the upper side of the handle. The factor of safety (1.4) could be improved by eliminating the sharp corners where the handle connects to the part.

The design of the handle will support twice the weight of the actual part with a factor of safety of about 2. At the actual weight of the part, the stress would be half of what is shown in the simulation. This means that if the handle were to experience only the weight of the parts, the stress would always be four times less than the yield stress of HDPE. The specifications were to support double the weight to account for the weight of contents inside the box. When the handle is held unassembled (supporting only the top half) the applied load would have to be greater than 180N for the part to fail. Assembled, the load would have to be greater than 361.63N for the part to fail. These loads are far more than the part should experience for applied weight conditions. The analysis that was run for the assembled part was very conservative. The analysis was run as if all of the load would be acting on the weak side of the handle,
when actually the load would be distributed between the two halves of the handle.

Overall, the design should be sufficient for specified loading conditions. The weight of the design was reduced while keeping the same wall thickness, which increased the safety factors, which were all above the target of 1.5. This should ensure that the parts will last the desired 10 years.
Appendix