Extrusion Blow Molded Cornhole Board

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Abstract

The cornhole board adds an element of fun to every summer event. This extrusion blow molded product requires no secondary assembly. Typical cornhole boards, both wooden and plastic, feature folding legs and a handle. The design allows ease of transportation and storage without the additional parts list. The redesign completely simplifies the cornhole board. High density polyethylene (HDPE) is the material of choice to produce this cornhole board.

Introduction

Cornhole is game for all ages. It is a staple at every outdoor summer event. Cornhole has several names depending on geographic location which include baggo, bag toss, and bean bag to name a few. The game can be played with either two or four people consisting of one or two people per team. Each playing board is placed 8.23 meters apart. Each team receives four 0.15 m by 0.15 m fabric sacks filled to an approximate weight of 425 grams. The game is typically played to a score of 21 points. A bag that goes in the center hole receives three points. A bag that lands and remains on the playing surface of the board is worth one point. If each team has a bag on the playing surface at the end of the round, those points cancel out. This works the same way if the first team has one bag on the board and the other team has a bag in the hole. The second team would receive two points for that round instead of three. The cornhole board is the main object required to play the game.

A blow molded cornhole board designed with simplicity in mind allows for no secondary assembly. This improved cornhole board design is both simple and convenient. The redesigned board is no longer an assembly by designing the legs into the sidewall of the part. Removing the legs from the board prevents any issues that could occur such as uneven legs or a broken leg feature. The only secondary operations required for this part consist of removing the flash around the perimeter of the part, as well as, within the hole. The final product could easily be customized by adding stickers of team logos, group names, etc. The redesign both optimizes and reduces the weight of the current cornhole board.

This part has several specifications that are critical to its use. These specifications include impact strength, rigidity, ESCR, and weatherability. The impact strength and rigidity of this product will be tested using ANSYS Workbench 16.1 for finite-element stress analysis.

The cornhole board follows the American Cornhole Organization dimensions. Extrusion blow molding allows the part to have double wall construction. The double wall allows the board to be lightweight and also improves its shock absorbance during impact. Figure 1 shows the design of the part.

Figure 1: Extrusion Blow Molded Cornhole Board Design Concept

The material of choice for this product is ExxonMobil™ HDPE HD 9856B. This high molecular weight resin provides ease of processing with excellent impact resistance, stiffness, and environmental stress cracking resistance [1]. The HDPE material family is cost effective compared to other molding materials such as polycarbonate.

Statement of Theory and Definitions

Product Description

Cornhole is a recreational event that typically played outdoors during the summer ranging from tailgating to graduation parties. The history of cornhole dates back to the 19th century. It has been traced back to the Native American Blackhawk tribe from Illionis, a farmer named Jebediah McGillicuddy from Kentucky, and even areas in Germany [2].

Currently, the game boards are either made of plywood or plastic. Plywood boards are assembled using screws, nails,
or bolts depending on the manufacturer. The plywood panels need to be cut to dimensions prior to assembly. Common regulation size plywood cornhole boards weigh about 12.4 kg each [3]. Plastic boards have a leg assembly to allow them to properly stand throughout the length of the game. The plastic boards weigh approximately 7.5 kg each which include the leg assembly [4]. These boards are an assembly which consists of an apparatus that allows the legs to fold under the board. Figure 2 below shows the current cornhole board design.

Hand calculations were completed using an equation from R.C. Juvinall and K.M. Marshek’s Fundamentals of Machine Component Design [6]. This equation was used to determine an equivalent static force of the bean bag impact on the playing surface which can be seen below in Equation 1. The force calculated from this equation acts on the product only for a short period. \( W_1 \) is the force of the bean bag. \( H \) is defined at the drop height of the bag. The term \( dst \) is the static deflection of the board under the weight, \( W_1 \). This value was determined from an initial analysis conducted on ANSYS. From the hand calculations, it is deemed that the contact force from the bean bag is 1,448 N. This value will be used for the ANSYS bean bag impact test to determine the strength of the product.

\[
F_e = W_1 \times \left(1 + \sqrt{1 + \frac{2h}{dst}}\right) \tag{1}
\]

Extrusion Blow Molding Manufacturing

Extrusion blow molding is a common manufacturing method within the plastics industry used to produce objects with a hollow interior. It is one of the three natural plastic production methods to produce hollow parts. The first patent for extrusion blow molding was issued to Celluloid Novelty Co. and Celluloid manufacturing Company, New York on February 1, 1881 [8]. The patent was for celluloid or similar plastic materials. The material options for extrusion blow molding have since increased dramatically. Blow molded parts can range in size from 0.03 L to 5000 L [7]. The market for extrusion blow molded parts is broken into two categories, industrial and packaging. Packaging consists of only bottles.

Extrusion blow molding starts with a thermoplastic material in granular or pellet form and ends in a hollow product. Figure 3 shows the process of extrusion blow molding, from plastic pellet to final product. Prior to starting the process, the die head will have to soak for one hour to several hours depending on its size [9]. Once the soak time has been achieved, material can be added to the hopper. From the hopper, the material enters the heated barrel where it is melted and mixed by a screw. Three to five heating zones wrap the barrel of the extruder. The heat rating of the heater bands range from 2-4 W/cm² [5]. The screw can either turn continuously or reciprocate after a shot is built depending on the machine capabilities.

The molten plastic enters the die head, which houses the mandrel, die, and blowpin. Once inside the die head the material flows around the plunger. The material then flows in between the die and mandrel to form the parison to the desired thickness. The parison is created once the material flows out of the die head. The parison continues to flow downward until the bottom of the parison is below the bottom of the mold.

The parison is clamped in between both of the mold halves. The blow pin then enters the cavity and inflates the parison using air pressure. Once the parison touches the mold walls the outer surface of the parison no longer moves [10]. The part begins to be cooled by the mold as soon as it touches the mold wall. Tooling materials with a high thermal conductivity should be used to reduce cycle time. The cooling stage of this process provides for 40 to 80 percent of the total cycle time [11]. When the proper cooling time has been achieved, the mold is then opened and the part is released.

Wall thickness of the part is difficult to control in extrusion blow molding. Blow ratio and the parison weight are the main drivers in the wall thickness. The optimum blow
ratio for extrusion blow molding is 3:1. Issues with uniform wall thickness or blown out walls will result if the blow ratio is too large. If the blow ratio is too small, there is a chance that the product geometry will not be formed by the blow pressure. Higher blow pressures will help to provide for a more uniform wall thickness [11]. This helps the parison reach the deeper draws before the other regions of the parison touch the wall and stop expanding. The parison weight drives wall thickness. If the bottom of the parison is excessively heavy compared to the top of the parison, there will be a difference in thickness. This difference in thickness will relate directly to part geometry. Parison programming can be used to prevent this issue from occurring. Parison programming is typically used for products with odd shaped geometries. These products need a specific parison distribution to be able to produce the desired geometry. This specific product does not require parison programming.

Continuous extrusion and intermittent blow molding are the two different production methods for extrusion blow molding. Continuous extrusion blow molding extrudes a parison continuously. The screw on the plastification unit does not reciprocate but turns continuously to deliver the melt. This method has a high throughput value because there are typically multiple molds used during production.

Intermittent blow molding holds the melt in the barrel and pushes out the material in one shot. Once the shot is built, the screw reciprocates and pushes the material through the die to form a parison [12]. Intermittent is typically used for large products. Material degradation can be an issue if a thermally sensitive material is used at a long cycle time.

**Process Advantages**

Extrusion blow molding offers many advantages compared to other plastics production methods based off of this product. Tooling costs and lead times are generally lower for extrusion blow molds. The tools do not go through the vigorous cyclic loading that injection molds are exposed to. Iron and steel are typical material used for extrusion blow molding tools [7]. Complex details and geometries can be created at a lower part cost because of the low tooling cost. The material does not see the excessive shear rates within injection molding. This means that the parts have lower stress compared to the injection molding products. With higher stress, stress relaxation can occur during the part lifespan which would could alter part dimensions and strength. The hollow geometry also allows the parts to be foam filled to add rigidity.

**Process Disadvantages**

Extrusion blow molding also comes with its disadvantages for this product. A high surface quality is hard to achieve with this process. It is typical to see drag marks produced from the material contacting the die. Tight tolerances are not achievable with this production method. Deep corners are also hard to fill because the parison stops moving as soon as it touches the mold wall. Secondary operations are always necessary to remove the flash that is created by the pinch offs.

**Machine Selection**

A possible machine option to manufacturing this product is the Uniloy Milacron UMA 85. The accumulator size of this machine exceeds the required capacity for this part. The platen sizes are large enough to fit the 1.6 m by 1.0 m by 0.7 m mold. The maximum clamp stroke is 1.7 m which is above the necessary opening stroke to remove the part from the mold. The 120 Extruder would be required for this machine to provide for adequate material throughput. The GP 212 accumulator is required to provide the necessary capacity of HDPE required for processing. The accumulation capacity of this machine is 22 kg HDPE. Complete machine specifications can be found in the Appendix. Figure 4 below shows a front and side view drawing of the machine.

**Design Specifications**
There are several specifications that determine the success of this product. Two forces that will act on this product will be tested. These forces include impact and static loading. Impact of the bean bag on the part surface occurs while playing the game. Impact strength of the product will be tested using finite element analysis focusing on yield strength. Static loading could occur during storage, if an object is placed on the cornhole board. Finite element analysis will be used to analyze yielding, as well as, deformation of the part. For both of these tests, ANSYS Workbench 16.1 will be used. The part will be full constrained in the six degrees of freedom to ensure the results are reliable. The product symmetry will be used to provide for better results from the simulations.

The environmental stress cracking resistance (ESCR) of this material is a point of interest due to the storage of this product. During storage, whether it be in a garage or shed, the part could come in contact with motor oil, windshield washer fluid, or even common household chemicals. The ASTM D1693-15 test for ESCR of ethylene plastics will be used to determine the chemical resistance of this specific grade. Condition B will be the condition of choice. Weather testing is important in the situation that the cornhole board is left outdoors. The ASTM D1435-13 test for outdoor weathering of plastics will determine the product lifespan if it is to be left outdoors for an extended period of time. The specimen for this testing procedure can be any shape or size. It should be placed on a rack in a region in which the climate represents the conditions that the product will be under. The duration of the test is in terms of months [13].

**Current Material**

Cornhole boards are typically made out of either plywood or HDPE. Wooden boards are typically used because of the sturdiness. The boards are also extremely heavy weighing around 12 kilograms. Unfortunately, wood will sag and warp if left in the elements. The use of this HDPE blow molding grade material from ExxonMobil™ will provide rigidity similar to wooden cornhole boards. This material will also provide a significant decrease in the weight of these products. Weathering and chemicals will no longer be an issue if left outside or a spill occurs.

**Design Validation**

Impact strength of the cornhole board is of utmost importance. For the testing, the product will have to absorb the impact of a 425 gram bean bag from 3 meters in the air. This resembles actual playing conditions during a cornhole game. A force of 1,448 N will be placed on the center of the board 300 mm from the front of the board. This force will be acting normal to the face of the playing surface. This will be the weakest point of the board because there are no sidewalls near by to add rigidity. The test will be deemed successful if the stress in this region does not exceed the yield strength of the material.

Static loading will resemble the storage of the cornhole board under the circumstance that a heavy object was placed on the face of the board. For testing, the part will need to endure the static loading of a 23 kilogram object resting on its playing surface. A force of 220 N will be applied to the face of the board. This force will be acting normal to the face of the playing surface. The spot of interest for this test is the cross section of the playing surface. This will replicate a heavy object will a large surface area resting on the cornhole board during storage. The test will be considered a success if the top wall of the part does not come in contact with the bottom wall of the part.

ESCR is important if the product is being stored with a load. Any chemical coming in contact with the product could cause a failure. These chemicals range from common household cleaning products to motor oil. The ASTM D1693-15 test for ESCR of ethylene plastics will be the testing method to determine the resistance of the HDPE. Condition B will be the condition used for the standard test. This condition uses a thickness ranging from 1.84 mm minimum to 1.97 mm maximum at 50°C with a notch depth of 0.3 mm minimum to 0.4 mm maximum depending on the specimen thickness. Ten notched specimens are to be placed in the apparatus for ten minutes. After ten minutes has concluded, the apparatus is to be submerged in the chemical. The fixture should have approximately 13 mm of liquid above it [14]. A successful test would consist of a specimen that has not been effected by the chemicals while under stress.

Weather testing the material used for this product is important in the instance that the product is left outdoors to endure the elements. The ASTM D1435-13 test for outdoor weathering of plastics will be the method used to determine the weatherability of the HDPE. Specimens of any shape and size will be left outdoors in a fixture to endure the elements for a specific time frame in months. The specimen will be the same thickness as the part wall thickness to provide the most accurate results. A control group that will remain unexposed to the elements will be kept for visual comparison. After the specified time frame has been reached the specimens will be reviewed. Success for this testing method would include specimens that have no signs of deterioration due to the exposure.

**Design Procedure**

**Product Design**

The software used to redesign this product was PTC Creo Parametric 3.0 M070. The initial board design began as a
triangular shaped extrude. The playing board is 0.61 m wide with a length of 1.22 m. The front of the board is raised 0.076 m from the resting surface and the rear is 0.305 m. This height difference places the playing surface on a 19 degree angle. Figure 5 below shows this initial sketch of the part. Figure 6 below shows a dimensioned top view of the part.

The next step of the model consisted of placing the hole regular to the playing surface. The hole is 0.15 m in diameter. It is placed 0.305 m from each side of the board and 0.23 m from the top edge of the surface. The inside of the part was then shelled out to produce its hollow triangle design. A wall thickness of 0.005 m was used for the part. An additional extrude of 0.032 m was added on to the back sidewalls of the part.

For rigidity and to help produce uniform wall thickness, the outer walls of the board are drafted at a 15 degree angle. Figure 7 below is a back view of the product showing the angled sidewalls. The additional length of the sidewalls and high degree of draft are the main drivers behind making this a functional piece with no additional parts. This draft angle allows for two cornhole boards to be stacked on top of each other to minimize the space required for storage.

The final stage of the design process consisted of adding rounds to all of the surfaces to soften the corners. Rounds of 0.013 m were to the top edge of the playing board. The same value was added to both the inner and outer edges of the front and sidewalls. The radii on the inside of the boards were also set at 0.013 m. The inner and outer edges of the hole were designed with a radius of 0.006 m.

Design guidelines were not followed for the rounds. They were not followed because if the rounds on the outer edge of the board were too large, the integrity of the game would be altered. Thinner rounds allow for the bean bags to remain on the surface if they are near the edge. If the rounds on the hole were too large, the diameter of the hole would be altered.

**Finite Element Analysis**

The cornhole part was transferred to ANSYS as a Parasolid file. A mesh was created using a medium relevance center with a relevance of 100. For both models symmetry was used to help improve the quality of the simulations. To simulate the double wall construction, the mesh was created inward. The smoothing was set at medium and the span angle center was set at coarse. This settings were used for both static structural analyses. The mesh can be seen below in Figure 8.
Figure 8: Mesh

The impact of the bean bag was a non-linear analysis because contact elements were needed. Frictionless contacts were added to the bean bag impact model to prevent the face of the board from traveling through bottom wall. An imprint was made in the Design Modeler on ANSYS. The dimensions of the imprint was 0.15 m by 0.075 m. These specific dimensions were used to represent half of the bean bag impacting the center of the board where the support is minimal.

Contact elements were used to prevent the top surface from passing through the bottom wall. The top of the bottom wall used as the contact body. The bottom of the top surface was used as the target body. An offset of six millimeters was used to place the contact and target constraints on each of the surfaces that would come in contact. Shell thickness effect was not used for this analysis. Table 1 below shows the mesh statics for the impact of the 425 g bean bag on the surface. Table 2 shows the element name and number of those elements within the model. There were a greater number of element types for this analysis due to the contact elements used.

<table>
<thead>
<tr>
<th>Mesh Statistics (Bean Bag Impact)</th>
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<tr>
<td>Number of Nodes</td>
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<td>Number of Contact Elements</td>
</tr>
<tr>
<td>Number of Solid Elements</td>
</tr>
<tr>
<td>Total Number of Elements</td>
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Table 1: Mesh Statistics for Bean Bag Impact

<table>
<thead>
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<th>Element Matrix (Static Loading)</th>
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<tr>
<td>Element Name</td>
</tr>
<tr>
<td>SHELL181</td>
</tr>
<tr>
<td>CONTA174</td>
</tr>
<tr>
<td>TARGET170</td>
</tr>
<tr>
<td>SURF154</td>
</tr>
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</table>

Table 2: Element Matrix for Bean Bag Impact

A static structural analysis was used for the 220 N force over the face of the part. Due to the geometry of the part, symmetry was used. Symmetry prevented movement in the x direction. A displacement of zero was place on the front edge of the part to restrict movement in the y direction. A second displacement value of zero was placed on the front edge of the symmetry line to prevent movement along the z axis. These environment conditions can be viewed below in Figure 9.

Figure 9: Environment Conditions

Although the same settings were used for the model that had the 220 N force applied to the playing surface, a slightly different number of nodes and elements were present. Table 3 below shows the mesh statistics for the static loading model. This mesh consisted of two element types which can be found in Table 4.

<table>
<thead>
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<th>Mesh Statistics (Static Loading)</th>
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<td>Number of Elements</td>
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Table 3: Mesh Statistics for Static Loading

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<td>SURF154</td>
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</table>

Table 4: Element Matrix for Static Loading

Presentation of Design

Design Story

The goal of the cornhole redesign was to eliminate to complete simplify the current cornhole board design while cutting the weight of the board. The draft angle on the sidewalls allowed for the removal of the leg assembly that is on current cornhole boards. A fully dimensioned drawing can be reviewed within the appendix. The redesign weighs approximately 5.25 kg lighter than the wooden board and 0.35 kg less than current plastic boards.
The current wooden design with legs is present below in Figure 10. The legs create an assembly step. They can also break if the board is not taken care of.

**Figure 10: Current Cornhole Board Design**

**Material Selection**

The material of choice for this product is ExxonMobil™ HDPE HD 9856B. This material is both cost effective and easily processed. The material properties are well above the required strengths required for this application. HDPE is also an easily recycled material. It is the second most recycled material behind polyethylene terephthalate. The product is easily recycled after its lifetime has been exceeded because it is comprised of only one material. The HDPE worldwide product volume is nearly 27.2 billion kilograms [15]. Recycling this product after use will allow it to be manufactured into countless other products.

**Mold Description**

A dimensioned mold can be reviewed in the appendix. The designed mold is 1.6 m long by 1.0 m wide by 0.7 m tall. The part geometry determined that the parting surface of this mold would be required to be stepped. The open back of the product was the driver behind the stepped parting line. The estimated shrinkage for this product ranges from three to four percent [11]. Vents were placed around the parting line of the mold. The depth of these vents were 0.076 mm. This value provides for sufficiently venting without altering the parting lines and pinch off. If vents were not placed in the mold, uniform wall thickness could be affected.

Pinch off was determined by following the guidelines from lyondellbasell. Due to the part geometry, pinch is necessary around the entire perimeter of the part, as well as, within the hole on the playing surface. These dimensions provide for an optimum pinch to provide sufficient weld strength around the part. This weld is an air tight seal that wraps around the parting line of the product. Figure 11 below shows the pinch off dimensions used. The units used in this drawing are millimeters.

**Figure 11: Dimensioned Pinch Off**

The cavity half of the mold has a total of nine waterline circuits with a diameter of 19 mm. Eight of the nine water lines are offset from the angled part face. The last water line is located above the top corner of the part. The core half of the mold also have nine waterline circuits each with a diameter of 19 mm. The waterlines on this half are angled up and into the core to provide for sufficient cooling. To properly cut these waterlines, a gun drill would have to go through the sidewalls of the core. Although this is uncommon and the mold surface would need to be welded to patch the holes, the bottom surface quality of the part is not crucial. An isometric view of the mold can be seen below in Figure 12.

**Figure 12: Isometric View of Mold**

**Die and Mandrel Description**

The blow ratio for this part is nearly 1:1. The idea behind this is to produce a parison that is wider than the mold cavity. This is due to the significantly raised core and thin cross section. Figure 13 below is a section view of the die head assembly which includes the both the die and mandrel. The land between the die and mandrel is 0.006 m. The mandrel is angled at 60 degrees.
Finite Element Analysis Results

The wall thickness was based off of the static loading test conducted on ANSYS. A load of 220 N was placed normal to the surface of the cornhole board. A wall thickness of 0.006 m provided a von-Mises stress of 2.6226 MPa. This value is significantly lower than the HDPE tensile yield strength of 30 MPa. The total deformation from the force was 0.147 m. Several different wall thicknesses ranging from 0.002 m to 0.01 m were tested to determine the proper wall thickness for this product. Figure 14 below shows the von Mises stress results from ANSYS. Figure 15 below shows the total deformation results from ANSYS. These plots can be interpreted by looking at the legend on the land hand side. The color red shows the maximum value and ranges all the way to the minimum value which is blue. The maximum and minimum values are also labeled on the cornhole board.

The impact strength was determined using a load patch on the face of the product. This load patch can be seen below in Figure 16. The force determined from the hand calculation, 1448 N, was used for this analysis on ANSYS. This force was applied normal to the surface to represent a bean bag making contact with the board. The force that was used acts on the board in a very short time frame, almost instantaneously. The impact of the bean bag resulted in a maximum von Mises stress of 14.99 MPa near the front inner edge of the product. The von Mises stress recorded at the point of impact was 13.5 MPa. These values are still well below the yield strength of this material. Figure 17 below shows the von Mises results. The total deformation for this impact was 0.061 m which is considered to be minimal for the amount of time the force acts on the board. Figure 18 below shows the total deformation results from ANSYS. These plots can be interpreted by looking at the legend on the land hand side. The color red shows the maximum value and ranges all the way to the minimum value which is blue. The maximum and minimum values are also labeled on the cornhole board.
Conclusion

The cornhole redesign completely simplifies the current cornhole board design. This design provides a weight reduction of the current designs. The HDPE provides excellent impact properties and tensile strength to withstand the forces that will act on the cornhole board. No additional assembly is required with this part, which is not the case for the current products.

The design specifications were tested and confirmed using ANSYS Workbench 16.1 for finite element analysis. A 200 N force was applied normal to the playing surface to resemble the storage of an object on the product. The results provided minimal deflection and equivalent stress. The second analysis simulated a 425 gram bean bag hitting a load patch half way between the front edge of the hole and the front edge of the part. The results from this analysis showed a deflection and equivalent stress below the material’s yielding point.

Future Work

Tack-offs could be a possible focus to help improve rigidity. The addition of tacks would provide strength while decreasing the wall thickness. A decreased wall thickness would result in a final product with a lower weight. Unnecessary sections of the sidewalls could be removed to possibly help with weight reduction. ESCR testing should be completed to test the product in its environment. Accelerated weathering should also be conducted on this product. Other material options could be tested to improve strength, decrease wall thickness, and cut weight.

Acknowledgments

This design project would not be possible without the help from Mr. Jonathon Meckley. Mr. Meckley provided helpful information regarding the extrusion blow molding process and the design extrusion blow molds. A special thank you is directed towards Mr. David Johnson for providing crucial guidance in the ANSYS Workbench 16.1 analyses. Mr. Johnson also aided in determining a proper equation to determine the instantaneous force exerted on the cornhole board from the bean bag. An additional thank you is directed towards Mr. Jason Williams for reviewing and revising the product design to provide for the stepped parting line. Lastly, appreciation is directed to Penn State Behrend for the software used to perform both the design and finite element analysis on this product design.

References


Appendix
ExxonMobil™ HDPE HD 9856B
High Density Polyethylene Resin

Product Description
HD-9856B is a HDPE blow molding resin designed for high performance packaging applications. Containers made from HD9856B exhibit a unique combination of stiffness and environmental stress cracking resistance. These properties, coupled with excellent processability on both continuous and intermittent equipment, afford significant lightweighting and/or fast-cycling potential in many applications. HD-9856B does not contain any antistatic.

General
Availability
- Latin America
- North America
Additive
- Thermal Stabilizer: Yes
- Antistatic: No
Applications
- Caps and Closures
- Compression Moldings
- Food packaging
- Household and Industrial Chemical containers
- Pharmaceutical Packaging
- Thermoformed Parts

Revision Date: 03/01/2010

Resin Properties

<table>
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<th>Typical Value (English)</th>
<th>Typical Value (SI)</th>
<th>Test Based On</th>
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<td>0.957 g/cm³</td>
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<tr>
<td>100% Igepal</td>
<td>&gt; 1000  hr</td>
<td>&gt; 1000  hr</td>
<td></td>
</tr>
<tr>
<td>Impact</td>
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<tr>
<td>Tensile Impact Strength</td>
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<td>260  J/m²</td>
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Legal Statement
Contact your ExxonMobil Chemical Customer Service Representative for potential food contact application compliance (e.g., FDA, EU, HPFB).

This product is not intended for use in medical applications and should not be used in any such applications.

Processing Statement
1. Values are typical and should not be interpreted as specifications. Values may change with future development. 2. All molded properties were measured on compression molded plaques. 3. Blut Density: 585 kg/m³ (36.5 lbs/ft³) 4. Flexural modulus tested using Procedure A (11% x 0.125%), tangent calculation. 5. ES-CR tested using Condition B, 100% Igepal. 6. HD9856B has NSF recognition. Contact your ExxonMobil Chemical Representative for details.

Notes
Typical properties: these are not to be construed as specifications.

1 Product may not be available in one or more countries in the identified Availability regions. Please contact your Sales Representative for complete Country Availability.
Cornhole Board: Bean Bag Contact Force

Givens:
\[ dst = 0.05 \text{ mm} \quad g = 9.81 \text{ m/s}^2 \quad h = 3 \text{ m} \]
\[ \text{mass} = 0.425 \text{ kg} \]
\[ W_1 = \text{mass} \times g = 4.169 \text{ N} \]
\[ F_c = W \left( 1 + \frac{2}{1 + \frac{2 \cdot h}{dst}} \right) \]

Equations:
\[ F_c = W_1 \left( 1 + \frac{2}{1 + \frac{2 \cdot h}{dst}} \right) = 1448 \text{ N} \]

The force at contact of the bean bag is equivalent to 1,448 N applied to the imprint.