DOUBLE WALL CONSTRUCTION, EXTRUSION BLOW MOLDED DOG BED

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Abstract

Various styles of dog beds are currently manufactured. Variations include cloth beds along with plastic injection molded beds. Cloth beds stain easily and lack durability, while injection molded beds possess poor insulation properties. Using FEA analysis and the equation for thermal resistance, will prove producing this dog bed using the concept of double wall construction by means of extrusion blow molding will improve the product’s durability and insulation properties compared to the products currently produced.

Introduction

Few things in this world today can match the love between a man and a man’s best friend. No longer are dogs being seen as pets, but rather as members of the family. As a result, more effort is being put towards improving the quality of life for the canines. One way of improving their quality of life is by providing them with comfortable sleeping arrangements. Rather than sleeping on the floor or furniture, owners provide their own bed that serves as a place for the dog to relax and sleep.

Although the intent for this product is to provide an area for the dog to sleep, depending on the dog, the product, in some cases, is used as a chew toy. This causes problems with the beds made from cloth that can be easily torn. Though cloth beds provide more cushion and insulation, they tend to stain easily and retain odors. The injection molded beds would provide a greater resistance to stains and odors, however, the thin walls would offer little insulation and deform easily if chewed.

This design proposal is of an extrusion blow molded dog bed. Designing this bed using the concept of double wall construction will create a hollow space between the two layers of plastic. The air space between the top and bottom surfaces will act as an insulating layer to help improve the insulation properties of the product. The two-layered wall will also increase the durability of the bed, making it more difficult for the dog to tear and also crack if over loaded or handled roughly. A rigid high density polyethylene (HDPE) will be investigated further as a replacement material that will provide better melt strength and improved rigidity. Figure 1 is an isometric view of the proposed design.

Statement of Theory and Definitions

Currently, there are various types of sleeping units that are designated for dogs. These range from injection molded plastic tubs to oversized pillows. The beds are designed to provide an area for a dog to lie on while it relaxes or sleeps. Typically the beds are kept in the house or in the garage, and are placed on the floor. The majority of these beds are made from various cloth materials and stuffed with either beads, foam, wood chips, or spun polyester [1]. There are also a few variations that are injection molded out of polypropylene (PP) [2]. Depending on the type of bed and the behavior of the dog, the beds can last anywhere from a few months to a few years.

The pillows, or cloth beds, provide exceptional comfort and offer excellent insulation properties. Unfortunately, they are not very durable, they can hold odors, and can be torn and stained easily. Though most of the beds can be placed into a washing machine, excessive washing can weaken, fade, and distort the fabric and fillers. Eventually the odors will no longer come out and the fabric will weaken and begin to tear.

To create the cloth beds, initially, fabric is measured and cut to the specified lengths. The outer sleeve is then shaped and partially sewn together. Stuffing is then used to fill out the sleeve to the desired thickness, before the sleeve is completely sewn shut.

The plastic injection molded beds have slightly improved durability, and offer better resistance to stains and odors compared to the cloth beds. A disadvantage, however, is their insufficient insulation properties. The single layer of plastic allows heat from the dog to flow fairly easily through the plastic and into the cool floor.
An injection molding process begins with material being loaded into a hopper where it then falls into a heated barrel through a feed throat. A reciprocating screw shears and mixes the material as the barrel heaters heat it up to the desired melt temperature. As the screw rotates backwards, material is pushed in front of the screw and begins to accumulate. When the necessary shot size is reached, the mold closes and the screw is pushed forward to inject the material through a runner system and gate and into the mold. Water is circulated through cooling lines in the mold, and acts to cool the part so that it can be ejected without deforming. The final step, post ejection, is the removal of the runner and gate.

**Extrusion Blow Molding**

Extrusion blow molding is a simple and cost-effective process used to produce hollow parts. In both extrusion blow molding and injection molding, molds are used to shape the outer features of the part. Unlike injection molding, however, the extrusion blow molding process uses air pressure to shape the inside features of the part as opposed to a solid core. Attempting to produce hollow parts by means of injection molding would be difficult, as it would be virtually impossible to remove the core from the molded part. As a result, injection molded parts are typically limited to single walls.

Parts produced from extrusion blow molding processes generally fall within two market segments, including packaging and industrial. This process is most commonly used for the production of plastic containers and bottles, which fall under the packaging category. With this process, the size of the products can range anywhere from 0.030L to 3785L.

![Figure 2: Extrusion Blow Molding Process (Image courtesy of Higher Institute for Plastics Fabrication)](image)

To begin the process, material is loaded into the hopper and falls into a heated barrel. A rotating screw proceeds to push the material through the barrel while it is being melted and mixed. The molten material then travels through the head assembly, which consists of a torpedo, a die, and a mandrel. The material flows axially around the conical torpedo, located on the top of the mandrel to create the hollow tube. The hollow tube, or parison, then travels between the mandrel and the die to achieve the necessary diameter and initial wall thickness. As the parison continues to extrude downward, the two mold halves come together and pinch off the two ends of the parison. A blow needle or blow pin is then inserted, which blows air into the mold to expand and shape the parison to the mold. Waterlines that run through the mold halves will then cool the part so that it can be ejected without losing its shape. The final step is the removal of the excess material in the pinch off regions [3]. Figure 2 provides an illustration of the process.

The two major types of extrusion blow molding are continuous and intermittent. A continuous process involves the constant extrusion of the parison, while the intermittent process feeds the melt from the extruder into an accumulator that stores the material until the next shot. Continuous processes minimize thermal degradation and result in higher productivity. Intermittent processes are likely to cause thermal degradation, but are typically necessary for large containers that would require the production of a large parison in a short amount of time.

In most cases, depending on the design of the bottle, the diameter of the parison measures close to the diameter of the bottle’s finish. To avoid excessive thinning, the recommended ratio of the parison diameter to the part dimension, or blow ratio, is set at 3:1. It is possible to pre-blow air into the parison prior to the actual blowing phase, if a larger ratio is required.

Two of the main factors controlling the wall thickness of the parison include swell and parison sag. As the parison exits the die, the elastic memory and stress relaxation characteristics of the polymer force the parison diameter and wall thickness to swell and the parison length to shrink. The severity of the swell depends on the length of the die land and the shear rate as the polymer is extruded. The molecular weight distribution of the polymer and the elasticity of the polymer are also contributing factors. Knowledge of the amount of swelling that will occur is important for design purposes to minimize weaknesses that could occur near pinch off points and reduce flash [3].

Similar factors affecting swell affect parison sag as well. Parison sag is a result of the weight of the material being pulled downward by forces of gravity. This causes the material to behave oppositely compared to swell as it is thinned and stretched. This phenomenon results in a parison that remains thick near the bottom and thin at the top causing variations in wall thickness [4].
Wall thickness variation can also be affected by the geometry of the mold. As air is blown into the part, areas of the parison that hit the cold mold sooner will freeze while the remaining areas continue to stretch. As a result, the areas that first contact the mold are thicker while the deeper areas of the mold are thinner.

Although injection molding can hold tighter tolerances as a result of higher pressures and more uniform walls, various techniques such as Die shaping or Parison Programming can be used in order to improve the wall thickness variation of extrusion blow molded products.

Modifying the shape of the die using an ovalized die with a circular mandrel or an ovalized mandrel with a circular die, referred to as die shaping, can modify the shape of the parison. Parison programming also modifies the thickness of the parison by moving the mandrel up or down as the parison is extruded to increase or decrease the space between the die and mandrel [3]. Creating a non-uniform wall that is thicker near regions of the parison that require more stretching, will help create a final wall that is more uniform.

Unique techniques that can be accomplished with the extrusion blow molding process include the concepts of two-up modeling, double wall construction, and the ability to create tack-offs. The idea of two-up modeling can be explained by molding a single hollow part that is then cut down the middle to produce two individual parts. Rather than creating two separate cavities, the completely symmetric parts are molded together as one and then cut down the center to produce the two separate parts.

The concept of double wall construction is able to create a seamless two-layered part with a hollow center without requiring two separate layers to be welded together. The second layer gives the part added rigidity while the hollow center can serve as additional insulation. With this process, the addition of tack-offs can be incorporated into the design.

Tack-offs are compression welds that occur between the opposite halves of the extruded parison. The use of these features can improve the structure of the part by tying the opposite walls together. Tying the walls together will increase the strength of the part, which help transfer applied loads between them and reduce deflection.

There are a variety of tack-off designs that are useful for different types of loads. When structural enhancement is an important requirement for a product, ribbed tack-offs are typically the preferred design. The walls of the ribbed tack-offs help increase the stiffness of the part by acting similarly to structural ribs. Conical tack-offs are simpler to create and are the preferred choice for non-structural applications subject to more compressive loads [5].

Compared to extrusion blow molding, the process for creating a cloth dog bed is very time consuming and involves many steps. The process is not automated and requires a significant amount of manual labor.

Injection molding processes are able to provide tighter tolerances, better surface finishes, more uniform wall distributions, and result in less scrap than extrusion blow molding processes. With injection molding, however, tooling costs tend to be more expensive, molding parts with complex geometries can be difficult, parts tend to undergo more stress as they are molded, and hollow parts are very difficult to produce.

Though wall thickness variation as a result of parison sag and die swell can lead to inconsistent parts, this can be improved with the use of parison programming or die shaping. Areas that are pinched off as the mold is closed form excessive flash that needs removed from the part post ejection. In many cases, however, it is possible to recycle the material directly back into the process as regrind to minimize scrap. Cleaning the die ring and adding texture to a mold can help minimize the severity of drag marks that could affect the surface finish of a part.

Though the low pressures in extrusion blow molding make it difficult to attain tight tolerances, the proposed design is not of a high precision part, thus maintaining tight tolerances are not a concern. Problems with filling can be easily improved with proper design, for instance using appropriate rounds and incorporating draft to reduce thinning in deep corners and following the recommended 3:1 blow ratio.

Compared to the process to produce cloth beds, extrusion blow molding is considerably faster and requires significantly less manual labor. Compared to injection molding, tooling costs are much less and parts tend to experience less stress when they are molded. Extrusion blow molding also has the ability to produce hollow parts with complex geometries, and can be used to integrate multiple components of an assembly into a single part.

### Design Specifications

Finite Element Analysis (FEA) is a method used to predict how products behave under real-world conditions, such as applied loads, fluid flow, and other physical effects. By dividing the part into thousands of smaller elements, and calculating the behavior of each element, the software is able to predict overall behavior of the part. Behaviors include fluid flow, mechanical stress, fatigue and a variety of others. As a result, FEA will be used to predict the behavior of the product and validate the proposed design [6].
Though dog beds come in multiple sizes, this particular dog bed was modeled to accommodate medium sized dogs. When determining the specific requirements for the bed, the loads were defined based off of statistics provided for medium sized dogs. One requirement of the bed is for it to possess enough strength to be able to resist major deflection without exceeding the materials stress limit under the weight of the dog. A range of weights associated with medium sized dogs was found to be 18.14kg -27.22kg [7]. In order to simulate the dog lying on the bed, a weight of 40.82kg was used to provide a factor of safety of 1.5.

In many cases, dogs have a tendency to chew on objects within their surroundings, including their beds. Improving the durability of the product will help extend the lifetime of the product. Therefore, the bed must also be able to resist exceeding the stress limit of the material and major deflection if a dog were to bite it. Research showed that a study was conducted to measure the bite force of 22 medium to large sized dogs. A maximum of 141.97kg of force was recorded [8]. To simulate pressure from the bite, a rough estimation was made to create area to distribute the force that represented the size of a dog’s jaw.

Since some dogs are kept in the garage, it is necessary for the dog bed to provide good insulation properties especially in the winter. This will reduce the rate of heat travel from the dog through the bed and into the cold floor, and keep the dog warmer.

Thermal Resistance (R) is defined as the measure of the ability of a material to resist heat transfer per unit area. It is often used to calculate the effectiveness of insulation and is measured in K-m²/W. The higher the material’s thermal resistance, the more the material can prevent the heat transfer through its surface, and thus the higher the insulation properties. Equation 1 illustrates the equation used to calculate the thermal resistance per unit area of a material. The L value refers to the thickness of the specimen while the k value is the thermal conductivity of the material. For multilayer components, the thermal resistance is the sum of the R-values for each individual layer or component. This equation will be used to compare the insulation properties of the single layer injection molded dog bed to the multilayer extrusion blow molded dog bed [9].

\[ R = \frac{L}{k} \]  

While in the garage, it is also likely to be exposed to various chemicals that are stored there. These include oils, greases, antifreeze, along with household cleaning products. Since the proposed design offers simplified cleaning, it is necessary for the dog bed to be resistant to common household cleaners that could be used to clean the bed. Therefore, research will be conducted to determine specific chemicals that the material is resistant to.

The specific material that will be used to blow mold the dog bed is RIGIDEX® HM5060XA, produced by INEOS Olefins and Polymers, Europe. This is a high molecular weight blow molding grade material. A high molecular weight offers more entanglement, and results in good melt strength. The material is easily processed and can be used in the production of medium to large blow molded parts. It offers excellent chemical resistance, high impact strength, good rigidity, and enhanced ESCR resistance [10]. HDPE was also chosen because it can be easily recycled and easily colored.

Switching from the cloth material to a plastic material will improve the durability of the bed as it will not be as easily torn. Switching to a plastic material will also reduce the accumulation of stains and odors that can easily occur with the cloth material. An HDPE material was chosen over PP since HDPE materials typically offer higher melt strengths, a necessity for extrusion blow molding so the parison is able to maintain its shape and is not torn as it is being extruded. It was also chosen based on its excellent chemical resistance towards household cleaners and other chemicals found in the garage.

**Design Validation**

To ensure the design is able to meet the requirements for this product, FEA simulation software will be used to analyze the product performance under various conditions designed to mimic the product’s application. The surface of the dog bed where the dog will lay must be able to withstand a load of approximately 40.82kg, which translates to a force of approximately 400N. It must withstand this force without deflecting more than 6.0mm. The design must also withstand the force without exceeding the 26MPa tensile modulus of the material, since the part is more likely to fail in a tensile manner rather than in a compressive manner.

To simulate the pressure from a dog bite, the sidewalls of the bed must be able to withstand a pressure of 141.97kg distributed over an area of 2580mm². This translates to a pressure of approximately 0.5 N/mm². The maximum deflection of the walls must not exceed 6.0mm and the maximum stress must remain below the stress limit of 26MPa.

To further validate the design, hand calculations will be performed to compare the insulation properties of the two plastic bed designs. The new design must possess a thermal resistance at least ten times the thermal resistance of the single layer injection molded dog bed. Ensuring that the insulation properties are significantly increased will
improve the quality of the product and support the conversion to extrusion blow molding.

It is necessary for this product to be resistant to common household cleaners as well as typical chemicals found in a garage. Therefore, research will be conducted to determine specific chemicals that the material is resistant to, and future work will include ESCR tests that will be conducted on the chosen material using test bars of a similar thickness in order to ensure the material will not be weakened or corroded by the chemicals.

**Design Procedure**

In order to design this bed, extensive research was done on the various types of dog beds that are currently in the market. Although dog beds are sold in multiple sizes, a medium size was the focus for this particular design and comparisons were made to other medium sized beds. The initial design can be seen in Figure 3.

![Figure 3: Initial Design](image1)

The initial design for the bed was of a two-up design that would produce two beds each shot. With this design, the beds would be produced with only a single wall. Therefore, this design would not provide sufficient insulation for the dog. To improve the insulation, the bed was designed using double wall construction.

For this particular product, the inner dimensions of the bed were critical in order to ensure the bed would be large enough to comfortably accommodate a medium sized dog. Therefore, dimensions were taken from similar medium sized products online and at local pet stores and considered for the redesign. The major dimensions for the redesign were measured in millimeters and can be seen in Figures 4 and 5. Once the baseline dimensions for the bed were determined, the next step in the design process was to model the product using CAD software.

![Figure 4: Top View of Dog Bed, Dimensions in Millimeters](image2)

![Figure 5: Cross Sectional View of Dog Bed, Dimensions in Millimeters](image3)

The model started with a rectangular extrusion slightly larger than the required inner dimensions. Fifteen degrees of draft was then added to the extrusion for aesthetic appeal and also to provide for easy ejection. Rounds measuring a radius of 24.0mm were incorporated on the bottom edge and vertical edges of the part. Not only were these used for aesthetic purposes, but they were also incorporated to minimize thinning that could occur in deep corners of blow-molded parts.

To create the area where the dog would lay, a shell feature was generated on the top of the extrusion. The shell thickness was set at 12.0mm to leave room for the extrusion walls and the 3.0mm air gap between them. A cut was then extruded through the long side of the part to create an opening that will act as an entrance for the dog, and so the dog’s paws can hang over the edge. Rounds measuring a radius of 12.0mm were then added on the inner edges of the bed in order to maintain a uniform wall.

To form the double wall for the part, the 12.0mm thick walls were shelled to produce two 3.0mm walls and an air gap of 6.0mm. The wall thickness of 3.0mm was chosen based on the wall thickness of single walled dog beds measured in local pet stores to maintain a relatively lightweight product. If the FEA analysis indicates that the wall thickness is insufficient, a thicker wall will be used to provide the necessary durability required for the product’s application. Conical tack-off locations were then incorporated into the base of the structure in order to
improve the stiffness of the product. The design was completed after final rounds were added on the outer edges of the tack-offs and also in the corners of the entrances. Based on the volume of the part and the density of the material, the weight of the final product was calculated to be 2.75kg.

To blow mold the part, it will be oriented with the shorter ends facing in the vertical direction and the long ends facing horizontally, which can be seen in Figure 6. This will minimize the diameter of the parison required to form the part. The parting line of the mold will follow the outer edge on the top of the part, and the pinch off locations will occur along the outer edges of the short ends of the part. Placing the pinch offs on the shorter ends of the part will reduce the required pinch force and thus the required clamp tonnage.

To shape the part, air will be blown into the part through blow needles that will be located on the short end of the part, furthest from the die and mandrel.

To run an FEA analysis on the model, it was saved as a parasolid file and imported into ANSYS Workbench. Symmetry was defined along the center of the part to simplify the analysis. A mid-surface of the 3D body was then extracted to create a 3D shell of the model, which would provide more accurate results for the hollow part. A sketch was then imprinted on a wall of the bed to act as a load patch where the force of the dog bite would be placed. The patch measured 50.8mm wide, 76.2mm long, and expanded 12.7mm inward to provide a rough representation of a dog’s jaw.

Before adding the necessary loads and constraints, the part was assigned a mesh. For the entire model, the mesh relevance was set to 100. Face sizing of 2.0mm was added around the tack-off features too provide for a more accurate analysis where the part was expected to experience the highest level of stress. Table 1 highlights the mesh statistics that were used for this model.

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<th>Table 1: Generated Mesh Statistics</th>
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Figure 7 and 8 show the locations of the loads and constraints that were placed on the model. Displacement constraints in the “y” direction were placed on the bottom edges of the tack-offs to prevent the bed from moving downwards after the load was applied (Displacement A). A second displacement constraint was placed on a vertex near the center of the part to prevent movement in the “x” direction (Displacement B). With symmetry defined, it was only necessary to apply half of the force to the part. The analysis automatically accounts for the other half of the force. As a result, 200N of the total 400N force was applied to the top surface of the base to represent the force of the dog. Figure 7 shows the area where the 200N force was applied.

To accurately analyze the affects of the bite force, a nonlinear analysis was defined and a second load step was created to account for the potential contact that could occur between the double walls. For the second load step, possible areas of contact were defined on the inner surfaces of the load patch. The 200N force was removed from the base of the bed and the displacement constraints remained the same. A pressure measuring 0.5MPa was placed on the load patch and divided evenly on each side of the double wall to create a rough estimate of the pressure generated by each half of the jaw. The locations of the loads and constraints for the second load step can be seen in Figure 8.
Presentation of Design

The results of the FEA analysis indicated that the proposed design was able to withstand the required loads that were specified for the application of this product. The multicolored contours in the plots, generated by analysis, represent the location and severity of the response being measured, and correspond with the scale located on the left side of the plots.

Force of the Dog

The maximum equivalent stress plot shows the maximum stress that the product experienced under the applied load. For this particular plot, the stress was recorded in MPa, and the locations and levels of stress correspond to the positioning and colors of the contours, with the highest level of stress being red.

An analysis of the Maximum Equivalent Stress plot seen in Figure 9 indicates that the maximum stress on the part was found to be 5.279MPa, significantly lower than the 26MPa tensile modulus of the material. This confirms that the product will not exceed the maximum stress limit of the material or experience permanent deformation when subject to a force of 400N. This is three times the maximum load (134N) recommended for a single walled, injection molded travel carrier built for medium sized dogs. The load used to calculate the force (40.82kg) is also nearly one and a half times the average maximum load of medium sized dogs (27.22kg). Therefore, this product will possess a factor of safety of 1.5, which will increase the durability of the product and also accommodate for heavier dogs.

Pressure from the Dog Bite

The total deflection plot measures the maximum deflection the part is expected to undergo as a result of the applied load. For this particular plot, the deflection is measured in millimeters and the location and amount of deflection can be determined based off of the positioning and colors of the contours. The color red indicates maximum deflection, while blue indicates the minimum deflection.

The total deflection results from the initial load step of the FEA analysis further prove the success of the design. Figure 10 indicates a maximum deflection of 2.819 mm that occurred. This is less than half of the 6mm maximum limit specified for this part, providing a factor of safety of approximately 2.

Figure 11: Maximum Equivalent Stress, 0.5MPa Bite

The results of the second load step offered an additional validation for the proposed design. Figure 11
displays the Maximum Equivalent Stress that resulted from the pressure of the dog bite. The maximum stress recorded was 23.586MPa, which is lower than that of the tensile modulus of the material. The plot indicates that the maximum stress occurred in a very small area on the part, while the majority of the stress fell below 15.724MPa. As a result, the material does not exceed the maximum stress limit of the part and will not experience permanent deformation under the applied pressure.

Figure 12: Total Deformation, 0.5MPa Bite

The total deformation of the dog bed during the second load step can be seen in Figure 12. The maximum deformation that occurred was measured to be 5.108mm, just below the maximum allowable deformation of 6.0mm. Reducing the minimum wall thickness of the material to less than 3.0mm could potentially cause the part to exceed the allowable limit. Therefore, the wall thickness of the bed was kept at 3.0mm.

Insulation Analysis

Using the thermal resistance equation from Equation 1, the thermal resistance of the single layer injection molded dog bed was calculated. Research found that a common material used for the single layer beds was polypropylene and that the wall thickness measured approximately 3.0mm [2]. Using the thickness of the specimen and the thermal conductivity of PP, which was found to be 0.22 W/m-K, the thermal resistance for the single layer of the PP material was calculated to be 0.01364K-m²/W [11].

To calculate the thermal resistance for the extrusion blow molded bed, the thermal conductivity of the HDPE material (0.49W/m-K) along with the thermal conductivity of air (0.026W/m-K) was required [12], [11]. To estimate the thermal resistance, the individual R-values were calculated for each layer and then combined to give the total resistance. The combined R-value was calculated to be 0.262 K·m²/W, approximately 19 times the thermal resistance of a single layer of polypropylene.

Energy transfer occurs in the direction of high to low. Therefore, a higher thermal resistance will prevent heat radiating from the dog while transferring as quickly through the bed into the cool floor. Thus the dog will remain warmer longer. The calculations verify that the insulation properties of the proposed design were significantly improved. The requirement for an increase in insulation properties by ten times was almost doubled.

Material Analysis

Further research indicated that HDPE is used largely in extrusion blow molding to produce bottles that store various automotive chemicals, household chemicals, and industrial chemicals as a result of the high environmental stress cracking resistance and low permeability of the material. Some of the applications of the bottles include the storage of motor oil, antifreeze, disinfecting wipes, and dish detergent [13]. Therefore, it can be inferred that it is unlikely that the properties of the material will be affected or reduced if exposed to these chemicals.

Conclusion

The results of this study conclude that extrusion blow molding the dog bed using the concept of double wall construction, with the incorporation of conical tack-offs, will provide the necessary strength, durability, and insulation properties required to withstand applied loads that occur during the product’s application and out perform products currently produced. These changes will increase the lifespan of the product and improve the quality of life for the dog.

The FEA analysis proved that the dog beds would be able to withstand the 400N load requirement that the bed would experience under the weight of the dog. The analysis also proved that the bed would be able to resist the 141.97kg biting force of the dog without experiencing permanent deformation. As a result, the lifespan of the product would be increased since this design would offer more resistance to deformation and tearing compared to the single layer injection molded bed and the thin bed made from cloth.

Although the insulation properties would be lower compared to the cloth made bed, the thermal resistance calculations proved that the insulation properties of the extrusion blow molded bed were increased by almost 20 times, when compared to the single layered injection molded bed. As a result, the dog bed will remain warmer longer, which is important for the dogs comfort if the bed...
were to be placed on a cool concrete floor in a garage, especially during the winter.

Results of the material analysis concluded that switching to the plastic material would improve the resistance to stains and reduce odor retention compared to cloth. The RIGIDEX® HM5060XA HDPE material that was chosen was proven to provide the necessary strength to successfully withstand the applied loads. This material will also offer improved melt strength compared to PP to ensure the large parison will not be torn as it is extruded from the blow molding machine. Further research inferred that the HDPE material would provide the essential chemical resistance required for the specific application of the product.

Future Work

Before production of the final product can begin, a series of steps must be completed to finalize the efficacy of the design. A mold will need to be designed and a prototype constructed to ensure there are no design issues that would prevent optimization of the molding process. The prototype mold will also provide initial parts, which can undergo preliminary testing to further prove the product is able to withstand the required loads. This will be done using free weights that will be stacked evenly to match the 40.8kg requirement. The standard ASTM D695 test method for compressive properties of rigid plastics will then be used to measure the resulting stress and further prove that the actual product is able to withstand the bite force of a medium sized dog [14]. ESCR studies will also be conducted on the material to ensure it will remain unaffected by the chemicals while under stress. If the final tests reveal any flaws present with design, then a reevaluation will be performed on the design and the flaws will be subsequently modified.

Acknowledgements

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