INNOVATING BLOW MOLDING DESIGN FOR INTERLOCKING AND ILLUMINATED PLASTIC LANDSCAPE EDGING

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Abstract

This research study was performed to propose and evaluate a new plastic part formed by extrusion blow molding. The newly proposed landscape edging part would be created using a standard extrusion blow molding process, utilizing a two-up design. The newly designed part will boast sustainability, cost reduction, improved structural characteristics as well as have the ability for illumination. The new and modernized design was created to replace the current part which is manufactured from concrete.

Introduction

The blow molded part being evaluated in this research study is an extrusion blow molded landscape edging. The newly designed part will be molded to resemble the more expensive concrete landscape edging. Quality landscape edging creates clean, crisp lines between beds and other areas. It is most visible between a lawn and the adjoining garden, but landscape edging can define a flower border, a shrub bed, or the transition from a patio to the surrounding garden. It emphasizes the lines of beds, and it leads the eye to the next garden focal point.

The research study was conducted to better understand the design and performance of the newly designed plastic part solution for homeowners across the nation. Before the proposal of this design there is a few other renditions of this product but with disadvantages. The main push for the concrete to plastic conversion is the advantages which consist of sustainability, cost reduction, improved structural characteristics as well as the ability for illumination.

Statement of Theory and Definitions

Background on Landscape Edging

Edging is essential for the preservation of any paved patio, garden bedding, driveway and walkway. If edging is not used, you will find that the base and hence your edging will start to move and separate.

Edging was not always used in such a vast array of applications. They started their journey in post-war Europe, where after the destroying effects of bombing, edging were used to repair the streets and pavements.

Today edging is a widely sought after material for landscaping patios, walkways, driveways.

By securing the edges, you are securing your patio, driveway and walkway against the harsh elements of rain, snow and foot traffic. Edging helps maintain the appearance and quality of your landscaping. Edging not only have practical benefits, but it is also decorative. Edging can accentuate any garden plot or flower bed. In a sense edging puts a frame or border around the picture, that being your garden. It draws the attention and highlights the chosen areas [1].

Concrete Landscape Edging

Cement is a fine powder which sets after a few hours when mixed with water, and then hardens in a few days into a solid, strong material. Cement is mainly used to bind fine sand and coarse aggregates together in concrete. Cement is a hydraulic binder, thus it hardens when water is added.

Concrete is a solid material made of cement, water, aggregates and often with admixtures. When fresh, it has a certain workability and takes the form of the mold into which it is put. When set and hardened, it is as strong as natural stone and resists time, water, frost, mechanical constraints and fire.

For premade concrete landscape edging, the concrete must be mixed properly and then placed into a mold until the concrete cures, allowing for the mold to be removed. Forming concrete landscape edging is a very time consuming process when compared to an extrusion blow molded part due to this long cure time versus a thirty second molding cycle for plastic.

Another consideration in the concrete landscape edging production is the shipping costs and concerns. Concrete is a very dense material when compared to plastic, which increases shipping cost and greenhouse gas emissions based on the increased loading of the shipping equipment.

After the concrete has been shipped to the supplier or final site, there are still considerations such as set-up and disadvantages associated with the concrete landscape edging. The first major drawback is the ineffectiveness to interlock the edging pieces together. By not being able to
interlock the landscape edging together, a weak barrier is formed that is easily moved.

A second disadvantage to the concrete landscape edging is the inability to incorporate illumination. Adding illumination can greatly affect the aesthetics and the safety of the landscape edging. By providing illumination it not only positively increases the curb appeal of the surrounding area, but allows safe traveling at natural low lighting conditions such as at night.

**Competitor Information**

The major competitor in the plastics industry is EMSCO GROUP. EMSCO manufactures decorative lawn border products that resemble stone or brick but do not incorporate illumination into the design. Other competitors are manufacturing the concrete landscape edging systems which do not also incorporate interlocking or illumination features.

**Extrusion Blow Molding**

The process of Extrusion Blow molding is one of the simplest forms of producing plastic parts. Extrusion blow molding begins with the material being loaded into a hopper. From the hopper throat, the material is filtered into an extruder screw channel, and begins the feed phase of the process. Once on the screw and within the barrel of the machine, the plastic resin material is heated to a molten state, which is done during the metering phase due to mostly shear of the screw. A well designed screw will lead to a better mixing and melting of the material. The screw, driven by a variable speed motor, rotates to force the molten plastic material forward through a die head and mandrel. Two die heads that are used can be seen in Figure 1, which illustrates a diverging (left) and a converging (right) die head [2]. Typically diverging die heads are used when the products diameter are greater than 152.3 mm and a converging die head is used when the diameter is less than 127 mm.

![Diverging tooling](image1) ![Converging tooling](image2)

**Figure 1: Extrusion Blow Molding Head Tooling (Courtesy of B.E Klamecki)**

Once the material passes through the extruder it enters the head where the molten material is pushed through the die and mandrel. After the material travels through the die and mandrel, a parison is formed. A parison is a hollow tube of plastic. This tube should have uniform wall thickness, in most cases, depending on the final symmetry of the part. The parison is influenced by gravity, which can lead to sagging or a parison with a thicker bottom and thinner top. The final part may have a thicker base and thinner top [3]. If this occurs, it can greatly impact wall thickness and quality of the final product. If a part that is not cylindrical is desired then parison programming will need evaluated which allows the wall thickness of the parison to change, allowing the final part to achieve as close to a uniform wall thickness as possible.

Once the parison is extruded to the desired length, a two sided mold closes on the parison, which is illustrated in Figure 2. A blow needle then enters the area between the two parts and injects air to push the molten plastic into the final mold shape. The parison must be extruded just passed the depth of the mold so that when the part is pinched off it so it will create a seal for the blowing phase.

![Figure 2: Illustration of Blow Molding Process (Courtesy of CustomPartNet)](image3)

Once the part is cooled the mold then opens and ejects the product. Now the part is ready for examination. Since the parison must extend longer than the mold depth, the part must have a secondary operation performed to remove the excess flash. Once this task is completed the part can be sent out for other secondary operations or used for its application. This process can be continuous or intermittent within the same machine.

The first is a continuous extruder. It is called a continuous extruder due to the fact the extruder is continuously running. This type of extruder is typically used for the high speed production of bottles.

The second is an intermittent extruder. It is called an intermittent extruder due to the fact the extruder is running intermittently not constantly. This can be done by either using an accumulator or a reciprocating screw. Intermittent
is typically used for the production of larger container with a longer cycle time.

**Design Goals**

HDPE has a density of 0.941 g/cm³, and concrete has a density of 2.4 g/cm³ [4]. Since concrete has a higher density, the compensation of weight comes from the thinner wall thickness used in the extrusion blow molded part compared to the concrete part as well as the lower density. Since there is a wall thickness reduction, the weight can be expected to decrease by 88%.

Changing this process to extrusion blow molding also decreases the processing costs. It takes 72% less energy to manufacture plastic than it does compared to concrete [5]. The lower energy cost will allow the company to save money by using an extrusion blow molding process instead of the standard concrete process. Also, the smaller wall thickness of the parts have the ability to decrease fuel consumption. This will save greatly on shipping costs and the amount of time it takes to have a completed order shipped. This also allows the manufacturer to boast a more sustainable operation as a marketing campaign.

Another design goal is for the packaging to be able to withstand a load of 300 N on the rear surface without failing. This will be necessary, because these parts will be exposed the force of the stone, mulch or dirt that is in the landscape bed. Finite element analysis will be evaluated to determine if the newly designed landscape edging can meet this design specification.

Another design goal is for the packaging to be able to withstand a load of 1500 N on the front surface without failing. This will be necessary, because these parts will be exposed the force of a person, small tractor, or loaded wheelbarrow. Finite element analysis will be evaluated to determine if the newly designed landscape edging can meet this design specification.

The chemical exposure that this part may have to face is common lawn and environmental chemicals including: nitrogen, phosphate, potash and salt. HDPE is chemically resistant to all of these substances which allows it to perform well under these circumstances. This is a unique advantage over the concrete which will absorb all of these chemicals which can cause discoloration and cracking of the concrete.

**Recyclability**

HDPE is a good material in terms of recyclability. Unlike with the concrete, it is much easier to grind down the HDPE parts and reprocess them into material to be re-extruded again. This would involve implementing the regrind into the virgin material making the pellets for the blow molding process.

**Advantages and Disadvantages of HDPE**

A couple of advantages of HDPE for extrusion blow molding are chemical resistance, processability, and recyclability. The chemical resistance comes from the material’s high crystallinity which blocks the chemicals from penetrating the bonds to break them down. In terms of crystallinity, the part itself will have a higher chemical resistance the slower it is cooled.

The ease of processability for this material is from the low process temperatures that it can operate under. Also, this material is semi-crystalline, which makes it have a true melt temperature. What this means is that it will flow easier, requiring a lower injection pressure which will save on energy consumption.

The recyclability of this material is important because this allows the process to use regrind. In the research the material used was regrind. The reason that HDPE is a good recyclable material is because of its simple molecular structure which can be re-melted easily without degrading. Using recycled material can also allow the company manufacturing the product to boast sustainability.

There are, however disadvantages of using HDPE in injection blow molding applications. The first disadvantage being discussed is low yield strength. It does not take much pressure to make an HDPE part deviate from its initial geometry. This property of HDPE occurs because of its simple molecular structure and small amount of branching which allows the chains of the material to flow past one another more easily.

Another disadvantage of using HDPE in an extrusion blow molding process is its high thermal expansion. This is a disadvantage for extrusion blow molding because the product could be exposed to a temperature range of -40°C to 65°C. The thermal expansion occurs by the chains spreading about with the added thermal expansion.

The third disadvantage of using HDPE in an injection molding process is its flammability. Flammability of this material comes from its molecular structure. The ethylene group, which is what polyethylene is comprised of, give it the flammable properties and also gives it the nickname “solid gasoline.”

**Design Validation**

The design will be judged successful by its ease of molding without defects and by the performance of the part. A successful tool will provide adequate engineering and proper dimensioning to ensure that the interlocking
features function properly as well as ensure that shrinkage values are accounted for to ensure final dimension tolerancing is met and accounted for at all service temperature ranges.

The design specifications will be proven by running Finite Element Analysis (FEA) computer simulation on the part. The simulation will give estimations on how the part will perform under the given loads. Hand calculations were done on the loading to verify that the FEA results are accurate. To simulate an accurate model boundary conditions were applied that simulate that the base of the landscape edging is fixed.

Analyzing the part in ANSYS is an important aspect when determining the quality of the designed part. To ensure that the ANSYS results are valid a hand calculation was performed as well as analyzing the SEPC plot. The SEPC plot estimates the error that occurs in the mesh. The landscape edging part that was analyzed contained a mesh error of 3.96%, which validates the simulation error of the mesh. The number of elements used in this analysis was 149128 and the number of nodes was 149570. A fine mesh setting was chosen to obtain a low mesh error as validated by the SEPC plot.

A successful part will be judged on whether or not the part can withstand the forces of the part being exposed to by the landscape material that is being held back. The weight for the landscape material was calculated at 300 N. After using ANSYS simulation software it was predicted that an equivalent stress (VonMises) was experienced at 1.0907 MPa. This can be seen in Figure 4.

The yield stress of the HDPE material, which is 33 MPa can be correlated to the equivalent stress for failure purpose. Since the Factor of safety is beyond 30, the landscape edging product should not fail unexpectedly due to the material loading on the back of the edging.

A successful part will be judged on whether or not the part can withstand the forces of the part being exposed to by a person, small tractor, or loaded wheelbarrow. The weight for the landscape material was calculated at 1500 N. After using ANSYS simulation software it was predicted that an equivalent stress (VonMises) was experienced at 10.339 MPa. This can be seen in Figure 5.

The yield stress of the HDPE material, which is 33 MPa can be correlated to the equivalent stress for failure purpose. Since the Factor of safety is beyond 3.19, the landscape edging product should not fail unexpectedly due to the material loading front face of the edging.
A successful part will be judged on whether or not the part can withstand the forces of the part being exposed to by a person, small tractor, or loaded wheelbarrow. The weight for the landscape material was calculated at 1500 N. After using ANSYS simulation software it was predicted deformation of the edging would be 6.855 mm. This can be seen in Figure 7.

The blow-up ratio is compared with the maximum recommended blow-up ratio of the selected material. Blow up ratios of 2-3:1 are considered normal when molding commodity resins such as polyethylene. A blow-up ratio as high as 4:1 is a practical upper limit. As Figure 8 illustrates, the simulated model had an estimated blow-up range from 1:1 to 20:1. A more realistic blow-up ratio could be achieved by moving the parting line of the part. Originally, the landscape edging was simulated as a Two-up. Due to the blow-up ratio variation, in the future a single cavity simulation looking into another parting line location more centered will provide a more even blow-up ratio and minimize wall thickness distribution variation.

Wall thickness distribution is required to facilitate dimensional precision of the parison to ensure uniform wall thickness of the molded bottle. Uniform wall thickness is necessary for a minimum value of weight and impact strength ratio of a blow molded bottle. With constant wall thickness of parison the bottle of intricate shape produced may not have uniform wall thickness in the bottle. This is because the parison expands during blowing operation and parison stretches and it's wall thickness lowers. The extent of change in wall thickness depends on the amount stretching the parison undergoes. To overcome the problem of wall thickness variation in the finished bottle it is necessary to provide thicker wall where melt is expected to stretch and expand more and similarly provide thinner wall thickness where expansion or stretching is not much. Such wall thickness variations can be programmed on the parison control so that parison of suitable wall profile can produce bottles of intricate shape with uniform wall thickness in finished bottle.

Based on the illustration of the wall thickness distribution seen in Figure 9, the wall thickness varies from .03 mm to 1 mm. This would not be an acceptable wall thickness distribution. A higher quality wall thickness distribution could be achieved by moving the parting line of the part. Originally, the landscape edging was simulated as a Two-up. Due to the wall thickness variation, in the future a single cavity simulation looking into another parting line location more centered will provide a more even blow-up ratio and minimize wall thickness distribution variation.
Physical testing will be required to test the chemical resistance of the material. The testing will ensure that the packaging is fully functional to the user without the possibility of premature failure in the presence of lawn and garden chemicals.

Chemical resistance of the product will be based off of common lawn and environmental chemicals including: nitrogen, phosphate, potash and salt. For the chemical resistance tests the selected grade of HDPE will be molded into ASTM D638 tensile bars from the manufacturer. These tensile bars will then be submerged into the specific chemical bath for 72 hours at an ambient room temperature of 23°C and at 50°C. The tensile bars will then be tested in a tensile test compared to a control bar. A 30% or greater reduction in strength will be considered as a failure.

**Design Procedure**

The design process first starts with understanding the application of the specific part. After specifying specifications for the part, advancements could be made in the project. The first step was the designing the part itself; was the part going to similar or a completely new design. Extrusion blow molding typically consists of relatively simple geometries, so the challenge for this project was designing to meet the simple geometries as well as

After the part was designed it was crucial to determine a proper material to fit the specifications previously established. The end goal was to determine the cheapest material that would be adequate enough in meeting the design specifications. Finite Element Analysis was used on two specific materials: High Density Polyethylene and Polypropylene. After the analyses were run, it was determined to use HDPE material. Further physical testing as previously discussed in this paper will validate the successfulness of material and design of the product.

Initial sketches of the landscape edging started out as just a five-sided box with rough dimensions to match the current concrete design. After study and research the package was able to evolve. The next step in the design process was to incorporate the features that set the newly designed landscape edging part apart from the current products.

After the initial sketches, an intermediate CAD model was created. The addition of the interlocking side features, mounting brace for the metal stake, and feature for the adjustable LED light were incorporated. The intermediate blow molding design consisted of a completely enclosed part with wiring running on the base of the product.

Figure 11 illustrates the overall dimensions of the curved landscape edging piece in mm. The design was based on the average size of the current landscape edging on the market to adequately meet the market needs.

The finalized CAD models are illustrated in Figure 12 and Figure 13. This model represents a curved landscape edging that was modeled in CAD software. The figures illustrate the design features which have been added to allow this newly designed landscape edging to outperform the current standard. The recessed feature running along the upper back portion of the landscape edging is designed
so that a standard outside 25.4 mm LED rope light may be attached via an interference snap fit located in the center of the landscape edging. This interference feature securely fastens the landscape edging into place providing illumination to the landscape bed and adjacent walkway. The interlocking feature located on the left and right side of the landscape edging provides a structural connection from one blow to the next. The next feature on the newly redesigned landscape edging reflects is a simple and efficient staking position located inside the edging. A molded piece is driven into the ground with a metal stake and then the landscape edging utilizes a snap feature to lock onto the ground secured staking piece allowing for proper structural attachment. The bottom of the landscape edging also boasts being non-enclosed so that it may be pressed slightly into the ground to create a more unique and defined edge.

Figure 12: Final Isometric View of Landscape Edging Part

The interlocking feature provides a structural connection from one blow to the next. The newly redesigned landscape edging reflects a simple and efficient staking position located inside the edging. A molded piece is driven into the ground with a metal stake and then the landscape edging utilizes a snap feature to lock onto the ground secured staking piece allowing for proper structural attachment. The bottom of the landscape edging also boasts being non-enclosed so that it may be pressed slightly into the ground to create a more unique and defined edge.

Figure 13: Final Isometric View of Landscape Edging Part

Autodesk 3ds Max was incorporated into the project to gain aesthetically pleasing renderings of the finished product. Figure 14 illustrates a rendering of a brick colored and textured colored landscape edging product. Rendering a product before manufacturing allows marketing studies to be evaluated on the look of the finished product. Even if a product is designed to meet all structural and material specifications, the appearance of the product in the eyes of the consumer will ultimately be the selling point. Multiple versions and varieties of textures and designs can be tested using rendering software, which will enhance the overall quality of the product upon its launch.

Figure 14: 3ds Max Rendering of Brick Landscape Edging

Autodesk 3ds Max was incorporated into the project to gain aesthetically pleasing renderings of the finished product. Figure 15 illustrates a rendering of a stone colored and textured colored landscape edging product. Rendering a product before manufacturing allows marketing studies to be evaluated on the look of the finished product. Even if a product is designed to meet all structural and material specifications, the appearance of the product in the eyes of the consumer will ultimately be the selling point.

Figure 15: 3ds Max Rendering of Stone Landscape Edging
Due to the minimal pressures required for extrusion blow molding, a machined Aluminum mold base was selected. Aluminum will provide for exceptional heat transfer, which in turn has the potential to cool the part quicker.

In Equation (1) below, \( \sigma \) represents the normal stress on the part. \( F_n \) represents the normal component force which is represented in N. \( A \) represents the area that the load is applied and is usually represented in \( \text{m}^2 \). In Equation (1) the stress represents the tensile or compressive stress normal to the plane. Equation (1) is important by estimating the stress, because stress can be correlated with yield strength of the material to determine if the material will fail under loading which is often an overlooked design aspect in plastic part development.

\[
\sigma = \frac{F_n}{A}
\]  

Equation (1)

Presentation of Design

The purpose of this landscape part design is to provide a quicker and more cost effective alternative to the standard plastic and concrete edging currently available on the market. The current material used to produce this container is concrete. Through extrusion blow molding plastic an improved product can be achieved.

The polymer that will be used as a replacement for the concrete will be a HDPE. This grade is known for its rigidity, meaning it will be able to maintain its physical shape and resist deformation from various loads expected during transportation. Though HDPE has moderate chemical resistance it would be able to exceed the performance resistance specifications the current concrete part experiences. As well as being a high impact grade it is also able to protect the contents of the part from any falls or drops that may occur in shipping.

In order to provide concrete evidence that these specifications will be able to be met multiple simulation analyses needed performed. These will include the initial design of the part and mold using 3D modeling software such as Creo Parametric 2.0. From that model finite element analysis will be able to be conducted using ANSYS.

After the construction of the 3D model using Creo Parametric 2.0, that model will be imported into ANSYS to perform finite element analysis. ANSYS is used to closely approximate the effects of any structural or applied loads that the package may experience through its life cycle. These expected loads this part would see would be from transportation from impact and the loading from people, tractors, wheelbarrows and the landscape material.

Mold Design Considerations

The mold designed for this part application was designed specifically for the production of the newly proposed landscape edging in extrusion blow molding. There are several areas of the mold that need to be acknowledged to ensure an adequate design. This includes the mold material, and cooling lines and parting line location.

Due to the minimal pressures required for extrusion blow molding, a machined Aluminum mold base was chosen. Aluminum will provide excellent heat transfer, which in turn has the possible potential to cool the part quicker, allowing for quicker cycle times.

To ensure that the mold base does not become too hot and not be able to cool the parts sufficiently cooling lines were added to the mold. Cooling lines would need to be machined into the mold to assure that the mold would not heat up significantly as the machine/mold runs longer. The cooling in the mold consists of two circuits. The aluminum mold with embedded water lines provides cooling from one side of the part. The heat from the part transfers through the mold and into the water. The temperature of the water is usually set to about around a temperature of 15°C for HDPE processing.

The parting line location is a very important mold detail consideration that need to be evaluated before the mold is designed. By using data obtained from the wall thickness distribution and blow-up ratio with Polyflow simulation, a two-up mold is not desired in this application. Due to the wall thickness variation, in the future a single cavity simulation looking into another parting line location more centered will provide a more even blow-up ratio and minimize wall thickness distribution variation.

Conclusion

It is important to understand how extrusion blow molding of a plastic part can benefit the current industry. The functions discussed will boost sustainability, cost reduction, improved structural characteristics as well as have the ability for illumination. All of these advantages show that plastic is a great alternative to the current concrete and plastic standards.

Although a slight upfront cost associated with switching over manufacturing processes to accommodate the extrusion blow molding process would be costly, over the long term, the investment will be paid back due to the unique advantages and opportunities that plastic landscape edging can offer.

Since the plastics industry is such an inventive and continuously developing area of interest, it allows for the
research of alternative solutions for current products, increasing the performance and cost effectiveness of the part. The improved characteristics of plastics outperform concrete unanimously, allowing plastic to once again start another trend that would revolutionize the landscape edging industry.

Since there is a wall thickness reduction, the weight can be expected to decrease by 88%. Also by changing the process to extrusion blow molding this also decreases the processing costs. It takes 72% less energy to produce plastic than it does concrete [5]. The lower energy cost will allow the company to save money by using an extrusion blow molding process instead of the standard concrete process.

The chemical exposure that this part may have to face is common lawn and environmental chemicals including: nitrogen, phosphate, potash and salt. HDPE is chemically resistant to all of these substances which allows it to perform well under these circumstances. This is a unique advantage over the concrete which will absorb all of these chemicals which can cause discoloration and cracking of the concrete.

Overall it seems that the newly designed plastic landscape edging would provide a higher quality product over the currently available products available in the market. By using unique material characteristics and simulated part design, a new landscape edging solution is an attractive alternative.

**Future Work**

In the future, some other possible variables of the research project may be implemented to further investigate the design of the product. The current design transforms the current concrete design to plastic and adds certain features. The major advantage to the newly designed part is the ability to add illumination and an interlocking method to the landscape edging.

Additional steps would be required to completely test the newly redesigned plastic part. The mold would need to be prototyped to allow for preliminary parts to be tested. Extrusion blow molding prototyping can be obtained relatively inexpensively if an aluminum mold was built and contracts out the first prototype parts. The prototype parts would then be evaluated for functionality and structural integrity to ensure that the parts validates the FEA simulation results.

Future work involved with the costing analysis of the manufacturing switchover and part costing could also be analyzed in the future. Since extrusion blow molding companies are in the market to manufacture products for a profit, the financial department would need to determine an estimated payback period for the newly designed plastics part compared to the current standards.

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**References**


