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Computer Aided Design and Simulation of Bottled Water Handle

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Abstract: In this work, tools such as SolidWorks CAD, SolidWorks Simulation was used in the course of the design of a bottled water handle. This approach provided a less tedious process to its manual counterpart. Every progression of design was assessed and interpreted in detail in this paper. The primary goal of increasing the torsional rigidity and stiffness to be above 200 x 10^3 N-m/deg. was achieved from our computational Analysis; also, achieving a minimal weight of 0.0019kg for the test handle sample against 0.00206kg of the control handle sample obtained from India, never neglecting its ease to manufacture and ease of access. It is expected that the work will allow bottled water companies in Nigeria, who are notusing handles at the moment, to make appropriate decision on whether to seek the introduction of handles. It should also encourage bottled water companies to look inward and liaise with local plastic industries as regards to production of bottled water handles locally.

Keywords: Computer Aided Engineering, SolidWorks, Torsional Rigidity, Handle, Bottled Water

1. Introduction

Today, medical experts are encouraging people to drink water always for vitality. As a result of this, demand for bottled water has increased as people tend to carry water about.

[1] stated that the introduction of handle on bottled water started with the introduction of handles on large size extrusion blow moulded containers which made them more user-friendly, especially where the total weight of the package reached several kilos in household product containers, and where larger weights of 5 to 20-litre containers were involved. Therefore, it is no wonder that handles can be found on most large bottles today, including household chemicals, garden chemicals, automotive fluids, beverage containers (non-carbonated), edible oil bottles, and even the 1.75-litre liquor bottles [3].

[4] Also stated that blown handle technology in extrusion blow moulding dates back to the early 1960s. So, when polyethylene terephthalate (PET) came on the scene some 15 years later such handled bottles were already commonplace. Although easily achievable with extrusion blow moulding, the formation of a handle with an open window in the centre is difficult when using PET due to the inability to fuse the material together at the blowing temperature. PET bottles are blown at a relatively low temperature, which makes it challenging to form an integral seam - to seal both mechanically against leaks - around the perimeter of the window. In extrusion blow moulding, the temperature of the parison is close to the material's melt temperature, while in PET it is some 150 deg C below it. Also, any attempt to raise the temperature in PET for better pinching will result in a reduction in toughness and likely brittleness.

[1] However iterated that in some cases, moulds are incorporated with heated moveable segments that collapse the blown article to form the handle and bond the plastics at the periphery of the opening but as it stands now, no commercial activity ever followed this because of the difficult process.

Interesting technologies include attaching a handle by means of injection moulding after the blow molding step [1] and [4]. Here, the difference between blow moulding cooling time and injection moulding must be addressed, if the production rate is not to be greatly impacted [1]. Similar ring handles can be created during extrusion blow moulding by compressing a tab of pinched material. However, in Australia, bottles are produced using a similar approach in a two-step process, where a preform with a handle is injection moulded. An interesting addition is that the tip of the handle is connected to the body of the preform and after blowing it is connected to the body of the bottle, providing additional support [4]. The blow moulder is equipped with thermal insulating hats that cover the handle while the preforms are being heated in the oven [4].

The modern version of the inserted handle is one that is snapped into the bottle or preferably is placed into the mould, along with the preform, before blowing, and the bottle wall is formed around a protrusion in the handle to lock it in place [1]. This designs which is a significant part of juice bottle is called Pinch grip [1]. [4] Further stated that to provide the needed mechanical strength and minimize cooling time, the best cross sectional shape for the handle will be an I-beam design. However, this design does not really provide a robust feel when being held.

This work tends to design and fabricate a four cavity mould for bottled water handle that will solve the problem of gripping without the need of snapping it during blow moulding of PET. The cost effectiveness of the design and fabrication process and the mould capacity shall be looked into. Also, the durability, design improvement and the near steel strength of the handle product shall be examined.

However, introduction of injection moulded handles to be attached on the neck of the bottled water of smaller sizes of 1.5liters and the 0.75liter sizes has become necessary to enhance better convenience in carrying bottled water and increased acceptance by consumers.

This paper presents the design of bottled water handle for bottled water containers.

It is expected that the work will encourage bottled water companies to look inward and liaise with local plastic industries as regards to production of bottled water handles locally.

2. Material Selection for Handle/Design Requirements

The Material choice for the bottled water handle is polypropylene (PP). For the handle production, most manufacturers consider high density polyethylene (HDPE) and polypropylene (PP), [4]. But for this work our choice of polypropylene was influenced by its relatively higher yield strength as compared to high density polyethylene (HDPE), as well as the wider availability in various cross sections in the market [11] and [12]. Again, we considered the torsional stiffness as one of our major design target, Table 3 shows the result of our analysis, and polypropylene (PP) is far better than high density polyethylene (HDPE).

The design requirements of the handle are formed with reference to the attributes of control sample. They are formed with an aim of achieving optimized balance between the attributes [6]. Thus, design requirements are drawn up and categorized with the goal of prioritizing the attributes which are of higher importance towards the performance of the handle [7]. Prioritization makes sure that the handle is effectively and efficiently developed with finite resources within the limited amount of allocated design time.

These requirements are Performance Requirement, Fundamental Requirement and Auxiliary Requirement [8].

3. Design Approach of the Handle

It is important to note that, every aspect of designing, manufacturing and testing a mechanical component involves many technologies that contribute to the success of a given example. Like a tree in a forest, the sum of those contributions (e.g. each cell, leaf, and twig) determines how that individual entity develops and whether it succeeds [7].

However, utilizing knowledge learnt, experience gained, data generated, models created and the different concepts drawn from many literature, the design and analysis of the bottled water handle and mould was carried out in a systematic and systemic manner as outlined in the work Figure 1 shown below.

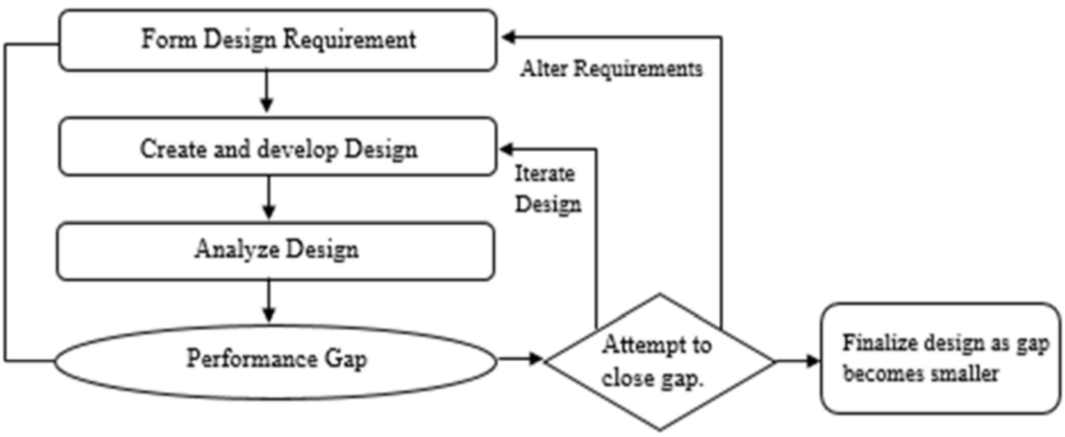


Figure 1. *Work chart of the design and analysis of the handle.*

3.1. Tackling Auxiliary Requirement

The manufacturability of the handle is tackled mainly through the selection of handle construction. By adopting the simple geometric handle construction, this attribute is achieved for the handle. Even though a slight compromise is made in term of ease of manufacture, this drawback is addressed through detailed planning of the manufacturing of the handle [10].

The ease of access and maintenance of the handle is tackled mainly through the packaging. The structural elements of the handle around those spots and areas are strategically relocated, with the aim of making the least possible compromise to the primary design requirements [5].

3.2. Tackling Fundamental Requirement for the Handle

The structural strength of the handle is tackled together with the structural stiffness of the handle because of their interconnected relation. Nonetheless, it is investigated at the final phase of the design and analysis of the handle. If there is insufficiency in the structural strength of the handle, the finalized handle model is refined, with the aim of making the least possible compromise to the structural stiffness [5].

Furthermore, the durability and reliability of the handle is tackled mainly through attaining high quality of build and strict execution of the maintenance schedule for the handle.

3.3. Tackling Performance Requirement for the Handle

The specific structural stiffness, particularly the specific structural torsional stiffness of the handle is the main focus for the design and analysis of the handle. It is tackled by varying the number of holders for both control and test sample [5].

4. Computer Aided Engineering (CAE) Tool

According to [2], SolidWorks CAD and Simulation software (hereafter refer as SolidWorks) is utilized for the design and analysis of the bottled water handle because of its exceptionally powerful capability in the field of design and analysis of engineering products. As SolidWorks is also the exclusive tool readily available at the time of this Thesis.

5. Calculations

With the importance of the handles' structural torsional stiffness realized, it is then essential to come up with the method of measuring and calculating the structural torsional stiffness. A method that is used in the industry for the design of different components is used and shown. This method is also included in the work done by [5].

It is covered in this thesis mainly on its concept of measurement and calculation. For more details, it is recommended that the local bottled water handle designers read the technical paper.

The structural torsional stiffness is calculated through finding the torque applied to the handle and dividing it by the angular deflection of the handle that is resulted from the torsional loading [5] and [9]. It is expressed in term of Nm/degree of angular deflection. This calculation is shown below in figure 2.

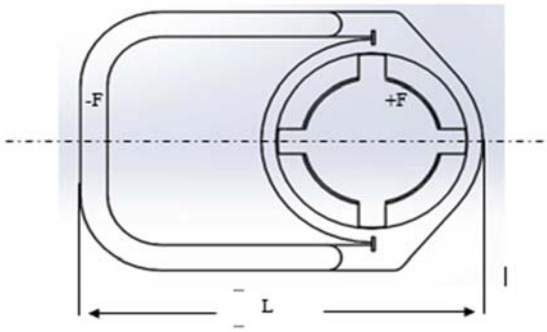


Figure 2. Calculation of structural torsional stiffness.

$$K_T = \frac{T}{\theta} \tag{1}$$

where,

K_T = Structural torsional stiffness

$$T = FL \tag{2}$$

T = Torque

F = Force applied

$$\theta = \mathrm{Tan}^{-1}\left[\frac{(y_1+y_2)}{2L}\right] \tag{3}$$

θ = Angular deflection

y_1 = Left vertical displacement

y_2 = Right vertical displacement

L = Width of measurement

The torque is derived from the product of the force applied at one corner of the handle and the distance from the point of application to the centre line of the handle.

The angular deflection is taken to be the angle formed from the center of the handle to the position of the deflected corner [3]. Both left and right vertical displacements are included in the equation to take the average vertical displacement in order to generate a more accurate estimate of the total angular deflection of the handle.

Equation 3.1 is utilized for the assessment of the structural torsional stiffness of the handle for its design and analysis. This equation is inputted into the spreadsheet and plotted to look for the coefficient. The coefficient is the structural torsional stiffness, K_T of the handle. All values needed for the equation are measured from the handle model in SolidWorks.

6. Analysis, Results and Discussion

6.1. Handle Sample Holders

Within the specified diameter of the bottle water, the holder is conceived. The handle model is analyzed and conceived by varying the number of holder for both the test sample and the control sample from four (4) to six (6) and the material from polypropylene to High density polyethylene [4].

After every parametric variation, the varied handle model is analyzed for structural torsional stiffness. The effect of the variation is investigated and the weight of the handle model is logged.

6.2. Mass

Table 1. *Material, Holder variation and Mass of the water bottle sample for both control and test.*

Sample	Material	Variation	Mass (Kg)
Control A	HDPE	6 Holders	0.00218
Control B	PP	4 Holders	0.00206
Control C	HDPE	4 Holders	0.00219
Control D	PP	6 Holders	0.00205
Test A	HDPE	6 Holders	0.002
Test B	PP	4 Holders	0.0019
Test C	HDPE	4 Holders	0.00203
Test D	PP	6 Holders	0.00188

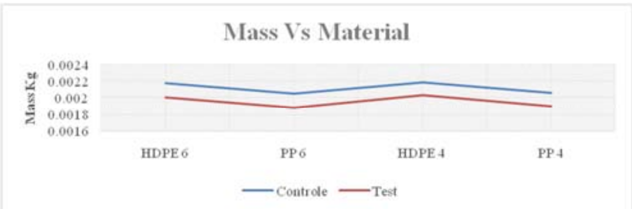


Figure 3. *Graph of Mass Vs Material of both the test and control sample.*

Both the control sample and the test sample's holder were varied from 6holders to 4 holders as the materials were also changed intermittently. For every variation the Mass was determined in Kg. The value obtainedis shown in the table 1.The PP material show less weight for every comparism of HDPE which is a plus for PP being better for this design [11].

6.3. Maximum Displacement

Table 2. *Material, Holder variation and Maximum Displacement of the water bottle sample for both control and test.*

Sample	Material	Variation	Maximum Displacement (m)
Control A	HDPE	6 Holders	0.201577
Control B	PP	4 Holders	$1.82165e^{-7}$
Control C	HDPE	4 Holders	0.200896
Control D	PP	6 Holders	$1.82783e^{-7}$
Test A	HDPE	6 Holders	0.42241
Test B	PP	4 Holders	$3.85004e^{-7}$
Test C	HDPE	4 Holders	0.424589
Test D	PP	6 Holders	$3.830282e^{-7}$

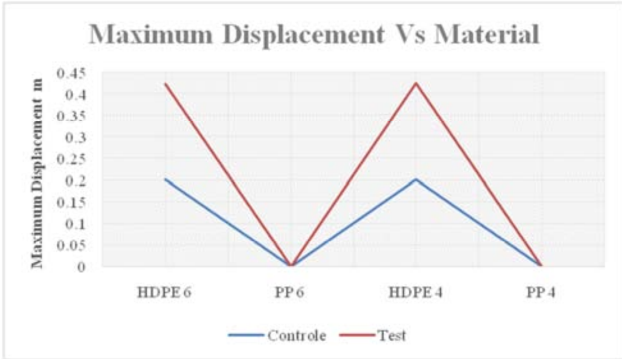


Figure 4. *Graph of Maximum Displacement Vs Material of both the test and control sample.*

Both the control sample and the test sample's holder were varied from 6holders to 4 holders as the materials were also changed intermittently. Each variation was analyzed for Maximum Displacement in other to utilize it to get the torsional stiffness. The Displacement plot of each sample is shown in the Appendix. The value obtainedis shown in the table 2.The PP material show less displacement for every comparism of HDPE which makes PP a better for this design [11].

6.4. Structural Torsional Stiffness

Table 3. *Material, Holder variation and torsional stiffness of the water bottle sample for both control and test.*

Sample	Material	Variation	Torsional Stiffness (Nm/Deg.)
Control A	HDPE	6 Holders	3571.84
Control B	PP	4 Holders	433356.68
Control C	HDPE	4 Holders	3583.94
Control D	PP	6 Holders	431981.55
Test A	HDPE	6 Holders	1704.51
Test B	PP	4 Holders	205082.52
Test C	HDPE	4 Holders	1695.76
Test D	PP	6 Holders	206140.51

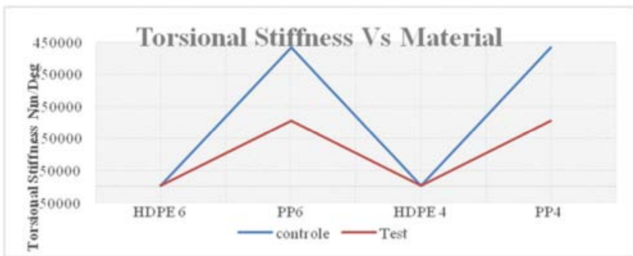


Figure 5. *Graph of Torsional Stiffness Vs Material of both the test and control sample.*

Both the control sample and the test sample's holder were varied from 6holders to 4 holders as the materials were also change intermittently. Each variation was analyzed for structural stiffness. The value obtainedis shown in the table 3.While the PP material show higher Torsional Stiffness for every comparism of HDPE which is yet another plus for PP being better for the design [11].

6.5. Summary of Analysis

From the analysis, 2 samples of both control and test handles (4 and 6 holders) were analyzed with both materials High Density Polyethylene (HDPE) and Polypropylene (PP) and the result shows that PP was the best material to be used as this applied to the test sample also. Again, after the analysis the test sample with 4 holders was chosen for production. It has the least weight, a torsional stiffness of above 200 x 10^3 N-m/Deg. Again, it was easier to produce as compared to that with 6 holders.

7. Conclusion

Through the execution of the top-down development methodology, a bottled water handle model is created. The proposed methodology tackles the design challenge through two major phases. They are CAD design of the product and analysis through variation of holders. With detailed and in-depth parametric investigation, the bottled water handle is thoroughly investigated, analyzed and designed. Multiple investigations were performed in order to understand more utterly the characteristics of the bottled water handle model.

One important feature that the proposed systematic and systemic approach has demonstrated is the design flexibility and versatility.

Finally, the tasks of the paper have been successfully completed. The development of the bottled water handle follows a top-down approach, in which all parameters that influence the performance of the produced model are categorized into major and minor clusters and tackled in a systematic and systemic manner.

Appendix

Table A1. *Analysis Information.*

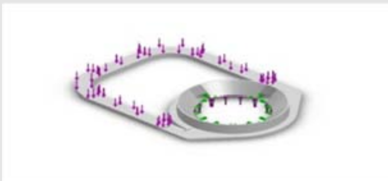
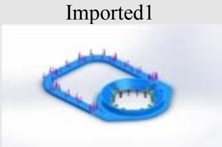
Model Information			
 Model name:Test sample1(pp) Current Configuration: Default			
Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Imported1 	Solid Body	Mass:0.001904Kg Volume:0.129942 in^3 Density:0.0322978 lb/in^3 Weight:0.018656N	C:\Users\Peter_\Desktop\Hillary's project files\Files\handle sample1(pp).SLDPRT Jun 07 18:20:00 2016

Table A2. *Load and Fixtures.*

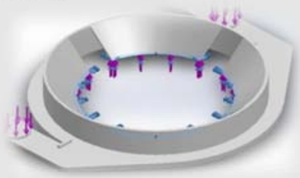
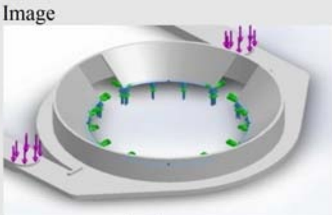
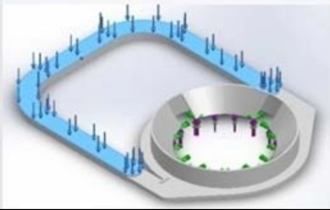
Fixture name	Fixture Image	Fixture Details	
Fixed-1		Entities: Type:	4 face(s) Fixed Geometry
	Load Image	Load Details	
Force-1		Entities: Type: Value: Phase Angle: Units:	4 face(s) Apply normal force 20 N 0 Deg
Force-2		Entities: Type: Value: Phase Angle: Units:	1 face(s) Apply normal force 20 N 0 Deg

Table A3. *Mesh Information.*

Mesh Information – Details	
Total Nodes	17245
Total Elements	8597
Maximum Aspect Ratio	18.156
% of elements with Aspect Ratio < 3	56.7
% of elements with Aspect Ratio > 10	0.523

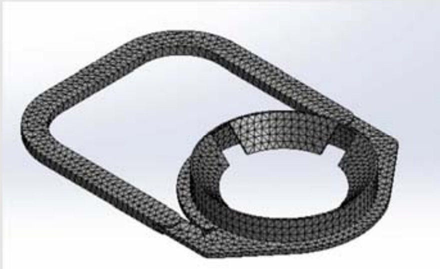
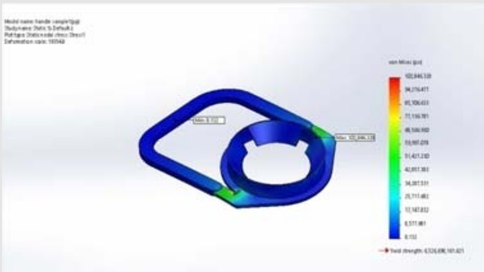


Table A4.*Resultant Forces.*

	Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction Forces	Entire Model	N	-0.000417	-59.492295	-0.002496	59.492295
Reaction Moments	Entire Model	Nm	0	0	0	0

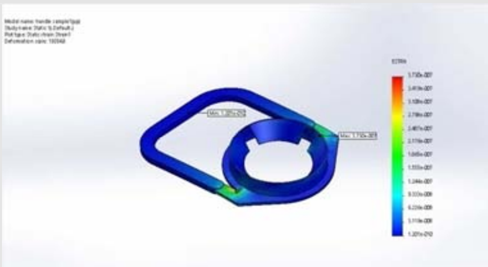
Table A5.*Study Results.*

Name	Type	Min	Max
Stress1	VON: von Mises Stress	8.13228 psi Node: 3007	102846 psi Node: 9888



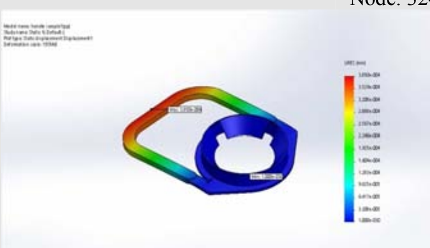
a. Test sample1(pp)-Static 1-Stress-Stress1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.20114e-010 Element: 493	3.72966e-007 Element: 407



b. Test sample1(pp)-Static 1-Strain-Strain1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 324	0.000385004 mm Node: 5257



c. handle sample1(pp)-Static 1-Displacement-Displacement1

Table A6.*Test Sample Factor of safety.*

Name	Type	Min	Max
Factor of Safety1	Automatic	10 Node: 1	10 Node: 1

Test sample1(pp)-Static 1-Factor of Safety-Factor of Safety1

Table A7.*Control Sample Factor of Safety.*

Name	Type	Min	Max
Factor of Safety1	Automatic	10 Node: 1	10 Node: 1

control sample2(pp)-Static 1-Factor of Safety-Factor of Safety1

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