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DESIGN AND FABRICATION OF A COST EFFECTIVE FOUR CAVITY PLASTIC INJECTION MOULD FOR BOTTLED WATER HANDLE

H. C. Godwin, H. E. Chukwu and M. C. Nwosu

Industrial/Production Engineering Department, Nnamdi Azikiwe University, Awka, Nigeria.

ABSTRACT: *Design and fabrication of a cost effective four cavity plastic injection mould for production of bottled water handle with locally available materials has been achieved. This research was appropriate considering the impact on sales of a sampled company that used handles for their bottled water before the scarcity of handles as a result of monopoly in importation. The clamping force which is a function of cavity pressure, cavity force and projected area was obtained as 243.2239N. The maximum deflection and the maximum bending stress were calculated to be 2.3282x 10^{-3}mm and 4.4677x10^{5}N/m^{2} respectively. The impact of the handle on the rate of return of the sampled company was tested. It was observed that before the introduction of handle, the Return on Investment (ROI) was approaching 30% and when handle was introduced, the ROI increased to 46.34% and 46.05% for the locally and foreign made handles respectively. However, the ROI declined to 34.41% when the handle was removed in both cases. This clearly shows that the handle has a great impact on the bottled water sales and market share for bottled water industries is expected to increase due to public acceptability. Also, the introduction of handle allowed for convenience in carrying bottled water especially the 1.5ltr. sizes.*

KEYWORDS: ROI, Bottled water handle, Regime

NOMENCLATURES

F_i – Cavity Force
F – Clamp Force
W – Uniformly Distributed Load (UDL) as a result of the Clamping Force
w - Load Per Unit length across the face of the mould, Uniform load on the beam
l – length of the beam, Length of the mould face
E – Modulus of elasticity
I – Area moment of Inertia
M – Maximum Bending Moment
b – Length of horizontal side of the cross-section
h – Length of vertical side of the cross-section
Q – Volume flow of the intended resin to be used
L – Length of Part being considered
d – Runner diameter
S_{max} – maximum wall thickness of the molded part
R – Hydraulic depth of Runner
S – Cross-Sectional Area of Runner
ΔP – Pressure loss at the Gate
μ – Viscosity of resin
F_E = Ejection Force
F_W = Ejection Load

ROI – Return on Investment

INTRODUCTION

Nowadays, Injection moulding represents a large portion of the entire plastics processing industry and plastic is now one of the most widely used material in the world, according to [1]. Among various plastic production technologies, injection moulding counts for a significant proportion of all plastic products from micro to macro components stated by [2].

According to [3], 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.

In Nigeria today, the standard size of bottle for bottled water are the 20liter, 1.5liter, 0.75liter and the 0.5liter bottled. The 20liter is for dispenser while the 1.5, 0.7 and the 0.5liters are used, most times to bottle water and can be carried about. The bottles are made with plastic material called polyethylene terephtalate (PET). It is usually blow moulded.

Introducing handles in bottled waters in Nigeria especially the 1.5 and the 0.75liter sizes has become necessary because of the expected influence of the handle on the rate of return on the company utilizing the handle.

This work tends to design and fabricate a four cavity mould for bottled water handle that will solve the problem of gripping by manually placing the handle on the neck of the bottled water during packaging. This is necessary because smaller sizes of PET are been used and the need to introduce handle to any of the sizes depend on the user. Also, some company reviewed has found the introduction of the handle on some sizes of their bottled water to improve their sales. This exposes the fact that the need for introduction of handle is based on choice and therefore the need to separate the handle from the PET.

Description of The Mould

Just like most moulds, the "four cavity bottled water handle mould" separate into two sides at a parting line, the "A" side, and the "B" side, to permit the part to be extracted. Plastic resin enters the mould through a sprue in the "A" plate, which branches out between the two sides through channels called runners, and enters each part cavity through one or more specialized gates. Inside each cavity, the resin flows around protrusions (called cores) and conforms to the cavity geometry to form the desired part. The amount of resin required to fill the sprue, runner and cavities of a mould is a shot. When a core shuts off against an opposing mould cavity or core, a hole results in the part. Air in the cavities when the mould closes escapes through very slight gaps between the plates and pins, into shallow plenums called vents.

To permit removal of the part, its features must not overhang one another in the direction that the mould opens, unless parts of the mould are designed to move from between such overhangs when the mould opens. Sides of the part that appear parallel with the direction of draw (the

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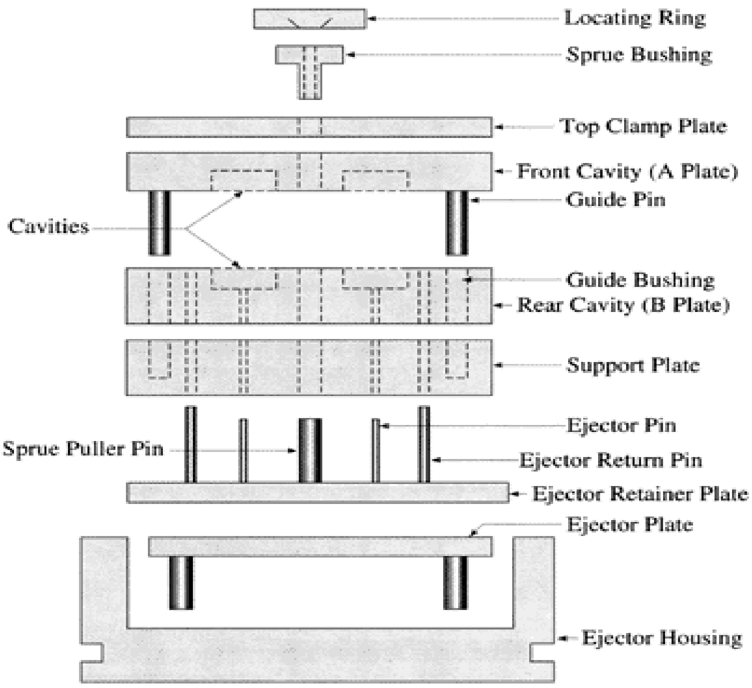
direction in which the core and cavity separate from each other) are typically angled slightly with (draft) to ease release of the part from the mould. Parts with bucket-like features tend to shrink onto the cores that form them while cooling, and cling to those cores when the cavity is pulled away. The mould is usually designed so that the moulded part reliably remains on the ejector ("B") side of the mould when it opens, and draws the runner and the sprue out of the ("A") side along with the parts. The part then falls freely when ejected from the ("B") side. Most ejector plates or pins are found on the moving half of the tool, but they can be placed on the fixed half if spring loaded. For thermoplastics, coolant, usually water with corrosion inhibitors, circulates through passageways bored through the main plates on both sides of the mould to enable temperature control and rapid part solidification.

To ease maintenance and venting, cavities and cores are divided into pieces, called inserts, and subassemblies, also called inserts, blocks, or chase blocks. By substituting interchangeable inserts, one mould may make several variations of the same part. Figures 2.1 below depicts moulds and it component parts.



Figures 2.1: Moulds and its Component Parts.

Design Considerations

During the mould design, these important considerations and precautions were taken to ensure that the mould meets the required international standard in mould design as in the works of [4] and [5]:

1. Material that will be most suitable for the design.
2. The clamping force for the mould.
3. Availability of material locally.
4. Maintainability.
5. Cost of manufacture.
6. Suitability to local consumers.
7. The cavity features was design to easy separation.

European Journal of Mechanical Engineering Research
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Design Specifications

The following design specifications were taken into consideration:

a. Mould should be able to withstand loading of 5tons.
b. Density of material used must be less than that of lead
c. The clamping position of the mould must be inculcated during design to prevent it from slipping.
d. Material used must withstand the melting temperature of resin (about 200^{o}C)
e. The mould is designed to have a proper resting base on the machine platens.
f. Tough and stiff Materials were selected to withstand maximum loading of 5 tons and ensured material does not wear easily.
g. The cavity must have uniform wall thickness.
h. Avoided sharp corners in the design. Sharp inside corners concentrate stresses from mechanical loading, substantially reducing mechanical performance.
i. Provided minimum draft angles or tapers of 0.5^o on all product features such as walls, ribs, posts, and bosses that lie parallel to the direction of release from the mould to ease part ejection.
j. The mould is designed so that the cores can separate from the part in the mould-opening direction.

Design Calculations

However, the method used for determining the required clamp force took the projected area of the part to be moulded and multiplied that number by a factor of 2 to 8tons per square inch. According to [6], the lower numbers can be used for high flow materials and the higher numbers can be used for low flow (stiff) materials. HDPE is used and it is a high flow material. Therefore, being on a safe side, an average of 5tons/in^2 was used.

5 * 6.894 757 x 10^{-3}MPa or N/mm^2 [conversion factor from lb$_f$/in^2 (psi) to MPa (N/mm^2)]
Cavity Pressure = 0.0345MPa.

Projected Area Determination

Figure 2.2 describes the cross-section of the bottle handle showing the dimensions and labels. The labels are showing figures that were used to calculate the projected area.

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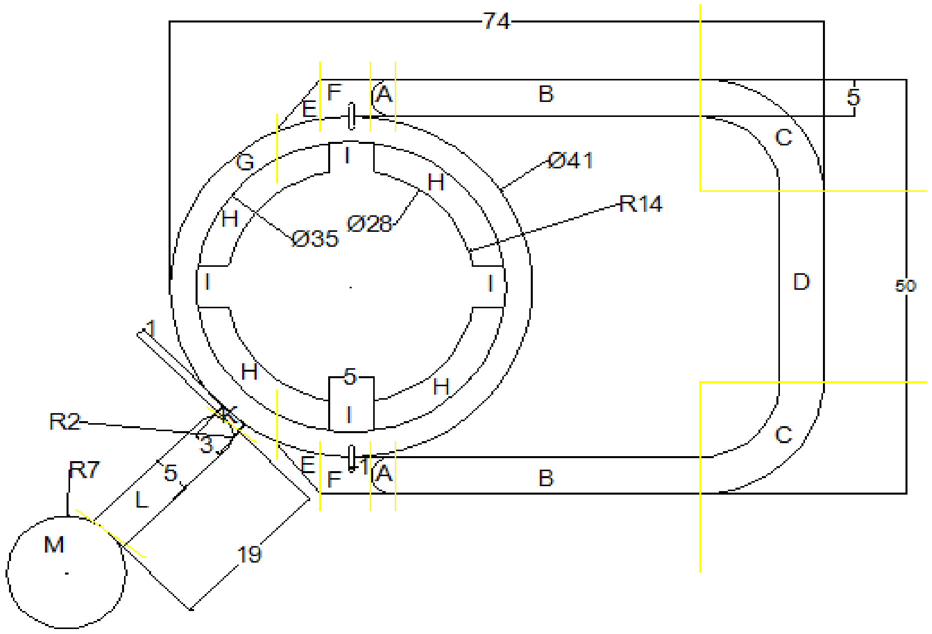

Figure 2.2: Cross-Section of handle showing the Dimensions and Labels

The average thickness of the product is estimated to be 2mm, hence estimated shot volume =6409.06*2 =12818.12mm^3.

Therefore, the projected area is **6409.06mm^2**; it substitute in equation (1) to obtain;

$F_i = P * A$ (1)
F_i – Cavity Force
P – Cavity pressure
A – Projected Area
$\therefore$ Cavity Force, $F_i = 221.1126\text{N}$
Therefore, Clamping Force, $F = 221.1126 + 10\%\ F_i$
$= 221.1126 + 22.1113$
$\therefore F = 243.2239\text{N}$

The force on the face of the mould which is equal to the clamping force is a Uniformly Distributed Load (UDL).

Determination of the Reactions R_A and R_B at supports "A" and "B".

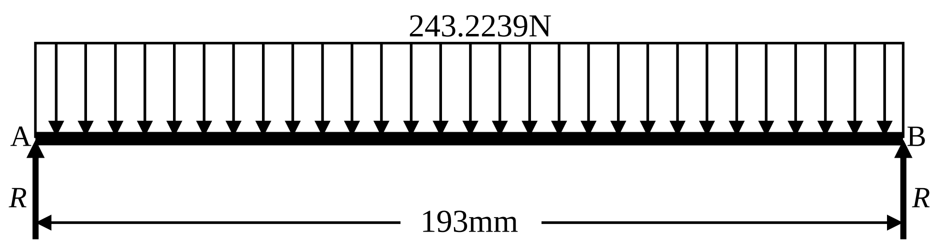

Figure 2.3: The Free Body Diagram (FBD) of the force acting on the face of the mould at maximum clamping force.

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

$R_A + R_B = W$ (2)

Taking moment about 'A', we have

For Equilibrium,

+ve

$$\sum M_A = 0 \quad (3)$$

$\therefore R_A = 121.6093N$ and $R_B = 121.6093N$

Determination of Shear Force (SF) Equation at any given point on the face plate

$V_x = R_A - wx$ (4)

$$V_x = 121.6093 - 1.2602x$$

Determination of Bending Moments (BM) on the mould

$$M = \frac{wx}{2}(l - x) \quad (5)$$

Note:

$$\frac{dM}{dx} = \frac{wl}{2} - wx = V_x$$

However, @ $x = \frac{l}{2}$, M has its maximum value

$M_{max} = 5.8676\text{Nm}$

Determination of maximum Deflection on the Mould

According to [4], Maximum elastic deflection (at the mid-point along l) of a beam under a uniform load is given as follows:

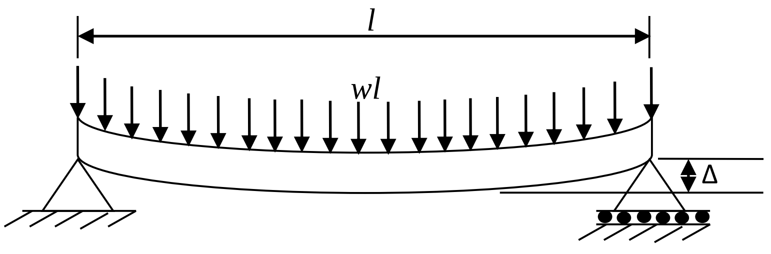

Figure 2.4: Rectangular face plate showing details of deflection

$$\Delta_{max} = \frac{5wl^4}{384EI} \quad (6)$$

Where,

w – Uniform load on the beam (force per unit length)

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

$l -$ length of the beam
$E -$ Modulus of elasticity
$I -$ Area moment of Inertia

For tool steel, E is at the range of 190 – 212. For the sake of this work, it adopt 190GPa = $190 \times 10^9 N/m^2 = 190 \times 10^3 N/mm^2$.

But,

$$I = \frac{bh^3}{3} \qquad (7)$$

$b = 197mm, and\ h = 20mm$

$$I = \frac{193 * 20^3}{3}$$

$I = 51466.6667mm^4$

$\therefore \Delta_{max} = 2.3282\text{x}10^{-3}mm$

Determination of maximum Bending Stress on the mould

The maximum bending stress for a rectangular cross section could be given as stated below according to [4].

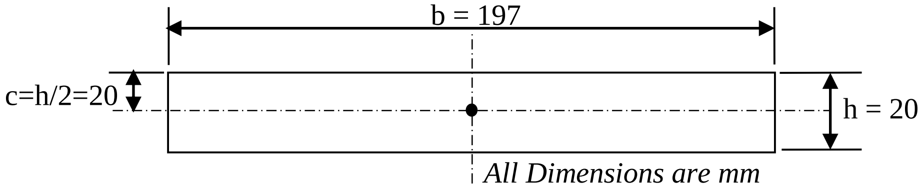

Figure 2.5: Rectangular Cross-Section of the face plate

Maximum Bending Stress, $\sigma_{max} = \frac{\text{Mc}}{\text{I}} = \frac{\text{M}}{\text{Z}} = \frac{6\text{M}}{\text{bh}^2}$

$$\sigma_{max} = \frac{6\text{M}}{\text{bh}^2} \qquad (8)$$

M – Maximum Bending Moment
b – Length of horizontal side of the cross-section
h – Length of vertical side of the cross-section

$$c = \frac{h}{2} \qquad (9)$$

$Z -$ Sectional Modulus, $\frac{I}{c}$

$\sigma_{max} = 4.4677\text{x}10^5\ \text{N/m}^2$

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The Material Selection

The choice of material to build a mould is primarily one of economics. To select the adequate material for the design, the first step was to translate the design requirements, which was done in section 2.1, into a material specification. Making reference to the Ashby's Chart according to [7], materials that fail constraints in the specification were screened out to obtain the go/no-go criteria. Then the next was ranking (an ordering of the materials that fall within the "go" criteria) by ability to meet objectives in other words called Material Indices. The promising candidates (materials) were sought for. The next step is to seek, from the subset of materials which satisfy the primary constraints, those which maximize the performance of the component. For instance, for the design of stiff components; the modulus E is plotted against density ρ, on log scales of the Ashby chart. The performance index (tension on stiff beam) is given as shown:

$$C = \frac{E}{\rho} \tag{10}$$

Taking logs of equation (1),

$$\log \mathrm{E} = \log \rho + \log \mathrm{C} \tag{11}$$

This is an equation of the form y=m*x* + b which is a family of straight parallel lines; one line for each value of the constant C. The slope is always 1 and log C is the y intercept. The index for bending on beam is:

$$C = \frac{E^{\frac{1}{2}}}{\rho} \tag{12}$$

Equation (3) will gives another family of lines, this time with a slope of 2.

The index for bending on light-stiff plate is:

$$C = \frac{E^{\frac{1}{3}}}{\rho} \tag{13}$$

Equation (4) will gives another family of lines, this time with a slope of 3.

All materials which lie on ISO-line of $\frac{E^{\frac{1}{2}}}{\rho}$ will perform equally well.

To obtain the optimum material, other Ashby material selection charts that highlight other material qualities were considered. They as stated below:

- Strength – Density chart: $\frac{\sigma_f}{\rho}, \frac{\sigma_f^{\frac{2}{3}}}{\rho}$ and $\frac{\sigma_f^{\frac{1}{2}}}{\rho}$
- Fracture Toughness – Density chart: $\frac{K_{IC}^{\frac{4}{3}}}{\rho}, \frac{K_{IC}}{\rho}, \frac{K_{IC}^{\frac{4}{5}}}{\rho}, \frac{K_{IC}^{\frac{2}{3}}}{\rho}$, and $\frac{K_{IC}^{\frac{1}{2}}}{\rho}$
- Modulus – Relative Cost chart. $C_R = \frac{\mathrm{c/kg\ of\ material}}{\mathrm{c/kg\ of\ mild\ steel\ rod}}$

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Finally steel was most favourd because it satisfies the criteria:

- Economic machinability
- Smallest change in size upon heat treatment
- Good polishability
- Great compressive strength
- High wear resistance
- Sufficient corrosion-resisting quality

Manufacturing Processes

Once the design is completed manufacturing begins. Mould making involves many steps which include:

- Marking-Out
- Milling and turning
- Heat-treating
- Grinding and honing
- Electrical discharge machining
- Polishing and texturing

To save cost, common mould components are purchased from suppliers e.g. bolts.

When all of the parts are completed the next step is to fit, assemble and test the mould. The mould must have venting features added to allow the air to escape as earlier stated in the vent design. At last, the mould must be tested to insure the products are correct and that the mould is performing properly.

The Operation Process Chart

The figure 2.6 below represents the operational process involved in the manufacture of the mould. The mould is made of two major parts, the cavity and the core. Under the cavity, are the female base plate, female face plate, the sprue bush and the locating ring. While on the core are the male base plate, male face plate, face plate support, locating pin, ejector plate and the ejector pin. Under each are circles and rectangular boxes that indicate the operations and the events taken to produce individual parts before finally assembling them to form the cavity and the core respectively.

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

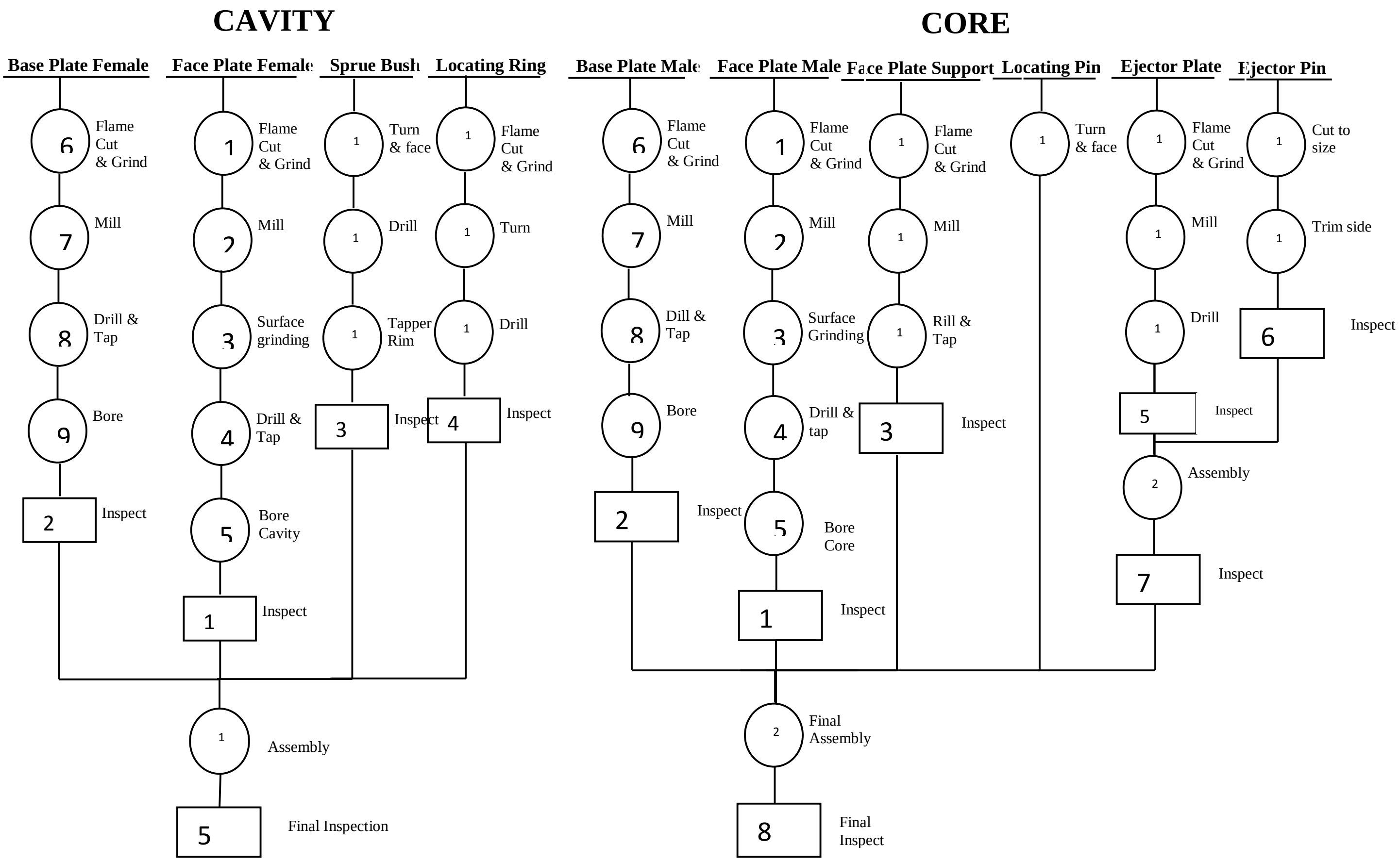

Figure 2.6: The operation process charts

Cost Analysis

For a 50kg material, revenue accrued is given as:
Revenue, R = Cost of Production, C + Profit, P

$$R = C * P \qquad (14)$$

Cost, C = Overhead + Transport + Material Cost
Profit, P = Markup, M * Cost, C
From [8] and [9],

Corporate Tax Rate	= 30%
Inflation Rate	= 7.9%
Interest Rate, i	= 13%

Weighted Average Cost of Capital (WACC)

$$\text{WACC} = \%\,\text{Debt} * i + \%\,\text{Equity} * r \qquad (15)$$

$$\text{WACC} = 0\% * 13\% + 100\% * 18\%$$

$$\therefore \text{WACC} = 18\%$$

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

Minimum Acceptable Rate of Return (MARR)

$$\therefore \mathrm{MARR}_{\text{Before Tax}} = \frac{\mathrm{MARR}_{\text{After Tax}}}{(1 - \text{Effective Tax Rate})} \qquad (16)$$

From Jeremiah et al, (2013), $\mathrm{MARR}_{\text{After Tax}}$ is at least equal to WACC

$$\therefore \mathrm{MARR}_{\text{Before Tax}} = \frac{0.18}{(1 - 0.3)} = \frac{0.18}{(0.7)} = 25.71\%$$

Therefore, Markup = 25.71%
For a 50kg material, the costs are attached as below:
Material cost = ₦10000
Transport = ₦500
Overhead = ₦5021.594
Profit, P = ₦3990.602

$$\mathrm{M_p} = 5021.594 + 500 + 10000 + 3990.602$$

$$\mathrm{M_p} = ₦19512.196$$

$$\mathrm{R} = \frac{\mathrm{R_a} * \mathrm{M}}{50000\mathrm{g}} \qquad (17)$$

R − Revenue from a handle

$\mathrm{R_a}$ − Revenue accrued from 50kg material

M − Mass of a handle (g)

After weighing the handle, it was observed that the weight is 2.314g; fraction of the runner, sprue and gate weight is 1.72g.

Therefore, 2.314 + 1.72 = 4.034g.
∴ Cost of a Handle ≅ **₦1.60**

Cost of Introducing Handle in a Company

Work Measurement

Table 3.1: Cycle Study Form

S/N	Element	Observed Time, OT (Sec)										Total OT	Ave. OT	R	BT
		1	2	3	4	5	6	7	8	9	10				
1	Hanging of Handle on Bottle water	10.8	10.6	10.5	10.7	10.6	10.4	10.4	10.3	10.3	10.4	105	10.5		
Note: OT = Observed Time, R = Rating, BT = Basic Time															

Table 3.2 above shows the "Cycle Study Form" and the time obtained for the element in the work measurement.

To obtain the extra cost incurred by bottled water company for introducing the handle, work measurement, which involves motion and time study, was carried out as stated in table 3.2 above:

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

$$T_{av} = \frac{\sum t_o}{N} \qquad (18)$$

T_{av} – Average time taken to fix one handle on a bottle

$\sum t_o$ – sum of observed time

N – number of observations

Average time taken to fix one handle on a bottle = 10.5sec

Average time taken to fix handles on one dozen = 10.5 x 12 = 126sec

Available working time in a month = 25days x 8hrs = 200hrs/month

= 200 x 3600 = 720,000sec/month

Average salary of a factory worker for a month = ₦18000

$$S = \frac{S_m}{W_T} \qquad (19)$$

S – salary of a staff per second

S_m – Salary for one month

W_T – Available working time in a month

$$\text{Average salary of a staff per second } = \frac{18000}{720000} = ₦0.025 \text{ per Sec}$$

$$L = S * T_d \qquad (20)$$

L-Labour Cost for hanging handles on a dozen of bottled water

S – salary per second

T_d – time to fix handle on one dozen

Therefore, labour cost of hanging handles on a dozen of bottle water = 0.025 x 126 = **₦3.15**

Other cost incurred as a result of introducing the handle for a dozen:

Transportation = ₦1.00

Disinfectant = ₦3.775

Total = ₦4.775

Recall, cost of one handle = ₦1.60

Hence, cost of handle for a dozen = ₦1.60 x 12 = **₦19.20/Dozen**

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

Therefore, extra cost incurred as a result of introducing Handle for one dozen = Cost of one Dozen of Handle + Labour + Other Cost Incurred

= 19.2 + 3.15 +4.775 = ₦27.125/Dozen

Tabulated costs of material for conventional bottled water

Table 3.2 Cost of one dozen of 50cl bottle water

S/N	Description	Quantity	Unit Cost (₦)	Cost (₦)
1	Bottle	12	15	180
2	Label	12	3	36
3	Water	12	0.15	1.8
4	Cover	12	2.5	30
5	Shrink wrap	1	5	5
			Total Cost	**252.8**

Table 3.3 Cost of one dozen of 75cl bottle water

S/N	Description	Quantity	Unit Cost (₦)	Cost (₦)
1	Bottle	12	17	204
2	Label	12	5	60
3	Water	12	0.225	2.7
4	Cover	12	2.5	30
5	Shrink wrap	1	7	7
			Total Cost	**303.7**

Table 3.4 Cost of one dozen of 150cl bottle water

S/N	Description	Quantity	Unit Cost (₦)	Cost (₦)
1	Bottle	12	21	204
2	Label	12	5.5	66
3	Water	12	0.45	5.4
4	Cover	12	2.5	30
5	Shrink wrap	2	7	14
			Total Cost	**367.4**

The above tables show the materials and their cost for making conventional bottled water without the consideration of the cost of handle.

Return on Investment (ROI) Analysis

In order to make decision on which of the investment regime to invest in, return on investment (ROI) analysis is used. This enabled us to choose which of the investment regime has a better return.

$$\mathrm{ROI} = \frac{R_i - I_c}{I_c} \qquad (21)$$

ROI- Return on Investment

I_c – Investment Cost

This analysis was done on the three regimes as stated below:

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

Considering the response of the locally made handle Before Handle Regime:

$$R_{BHR} = \sum Av_{BHR} \qquad (22)$$

R_{BHR} – Average sales of a dozen of the bottled Water sizes before handle regime

$$R_{BHR} = [\ (A_{50clBHR}) + (A_{75clBHR}) + (A_{150clBHR})] \qquad (23)$$

R_{BHR} – Revenue from Investment

$A_{50clBHR}$ – Average sales of 50cl bottled Waterbefore handle regime

$A_{75clBHR}$ – Average sales of 75cl bottled Waterbefore handle regime

$A_{150clBHR}$ – Average sales of 150cl bottled Waterbefore handle regime

$$I_{cBHR} = \sum A_{pBHR} \qquad (24)$$

I_{cBHR}
– Average Cost of producing a dozen of the bottled Water sizes before handle regime

$$I_{cBHR} = [\ (I_{c50clBHR}) + (I_{c75clBHR}) + (I_{c150clBHR})] \qquad (25)$$

I_{cBHR} – Investment Cost

$I_{c50clBHR}$ – Average Cost of producing a dozen of 50cl before handle regime

$I_{c75clBHR}$ – Average Cost of producing a dozen of 75cl before handle regime

$I_{c150clBHR}$ – Average Cost of producing a dozen of 150cl before handle regime

During Handle Regime:

$$R_{DHR} = \sum Av_{DHR} \qquad (26)$$

R_{DHR} – Average sales of a dozen of the bottled Water sizes During handle regime

$$R_{DHR} = [\ (A_{50clDHR}) + (A_{75clDHR}) + (A_{150clDHR})] \qquad (27)$$

R_{DHR} – Revenue from Investment

$A_{50clDHR}$ – Average sales of 50cl bottled Water During handle regime

$A_{75clDHR}$ – Average sales of 75cl bottled Water During handle regime

$A_{150clDHR}$ – Average sales of 150cl bottled Water During handle regime

$$I_{cDHR} = \sum A_{pDHR} \qquad (28)$$

I_{cDHR}
– Average Cost of producing a dozen of the bottled Water sizes before handle regime

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

$$I_{cDHR} = [\ (I_{c50clDHR}) + (I_{c75clDHR}) + (I_{c150clDHR})] \qquad (29)$$

I_{cDHR} – Investment Cost

$I_{c50clDHR}$ – Average Cost of producing a dozen of 50cl During handle regime

$I_{c75clDHR}$ – Average Cost of producing a dozen of 75cl During handle regime

$I_{c150clDHR}$ – Average Cost of producing a dozen of 150cl During handle regime

After Handle Regime:

$$R_{AHR} = \sum Av_{AHR} \qquad (26)$$

R_{AHR} – Average sales of a dozen of the bottled Water sizes After handle regime

$$R_{AHR} = [\ (A_{50clAHR}) + (A_{75clAHR}) + (A_{150clAHR})] \qquad (27)$$

R_{AHR} – Revenue from Investment

$A_{50clAHR}$ – Average sales of 50cl bottled Water After handle regime

$A_{75clAHR}$ – Average sales of 75cl bottled Water After handle regime

$A_{150clAHR}$ – Average sales of 150cl bottled Water After handle regime

$$I_{cAHR} = \sum A_{pAHR} \qquad (28)$$

I_{cAHR}
– Average Cost of producing a dozen of the bottled Water sizes After handle regime

$$I_{cAHR} = [\ (I_{c50clAHR}) + (I_{c75clAHR}) + (I_{c150clAHR})] \qquad (29)$$

I_{cAHR} – Investment Cost

$I_{c50clAHR}$ – Average Cost of producing a dozen of 50cl After handle regime

$I_{c75clAHR}$ – Average Cost of producing a dozen of 75cl After handle regime

$I_{c150clAHR}$ – Average Cost of producing a dozen of 150cl After handle regime

RESULT

The design was done with the proper engineering design procedure and the following results were obtained.

Table 4.1: Results from Mechanical Design

S/N	Features	Numerical Values
1	Cavity Pressure.	0.0345MPa
2	Projected Area Determination	**6409.06mm^2**

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

3	Clamping Force	243.2239N.
4	**Reactions at the supports R_A and R_B**	121.6093N
5	Determination of Shear Force (SF)	$V_x = 121.6093 - 1.2602x$
6	Determination of Bending Moments (BM) on the mould	5.8676Nm
7	Maximum Deflection	2.3282×10^{-3}mm
8	Maximum Bending Stress	4.4677×10^{5}N/m^2

The cost of introducing handle was determined; also the difference in the Cost/mass was obtained between the foreign and locally made handle and presented in the table below.

Comparism of Locally made handle and foreign handle

The locally made handle showed a significant reduction in weight to that of the foreign made handle. This reduction also shows that the material usage is reduced from the cost/mass ratio column. This in turn shows a reduction in cost of production.

Table 4.2: Comparism of Locally made handle and foreign handle

Handle Type	**Cost (₦)**	**Mass (g)**	**Cost/Mass Ratio (₦/g)**
Foreign	2.50	2.472	1.0113
Local	1.60	2.314	0.6914
Difference	0.9	0.158g.	0.3199

Financial implication of using bottle water handle

From section 3.2, the cost of handle was obtained as ₦1.60per handle. This value was in turn used to obtain the cost of introducing handle into the bottled water company in section 3.3 to be ₦27.125/Dozen. Furthermore, with reference to the sales data presented in Appendix AI, the rate of return on investment (ROI) as a result of this extra cost.

Considering the response of the locally made handle

Table 4.3: locally made handle responses

	Before Handle Regime (%)	**During Handle Regime (%)**	**After Handle Regime (%)**
Response of Locally Made Handle (ROI)	29.69312	46. 3441641	34.41213

ISSN 2055-6551(Print), ISSN 2055-656X (Online)

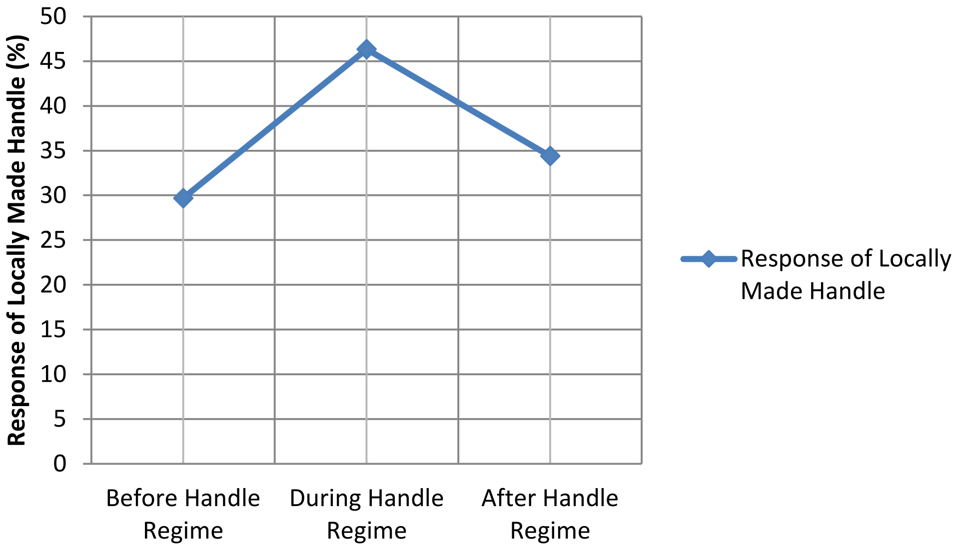

Figure 4.1: Response of Locally Made Handle.

The graph above represents the response of the Locally Made Handle. The graph shows that before the introduction of handle, the ROI was approaching 30% and when handle was introduced, the ROI increased to 46.34%. This increase is speculated to be as a result of increased acceptance of bottle water with handle. However, the ROI took a nose dive when the handle was removed to the tune of 34.41%. This is a 4.41% difference compared with the value before handle regime. This could be attributed to gain in market share which was not lost totally.

Considering the response of the foreign made handle

Table 4.4: foreign made handle responses

	Before Handle Regime (%)	**During Handle Regime (%)**	**After Handle Regime (%)**
Response of Foreign Made Handle	29.69312176	46.0466134	34.41212559

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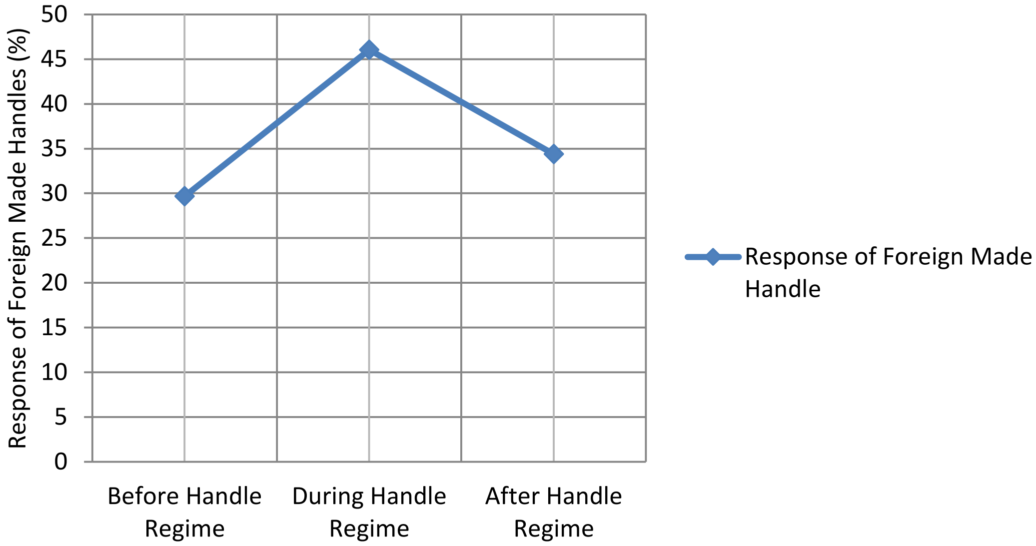

Figure 4.2: Response of Foreign Made Handle.

The graph above represents the response of the Locally Made Handle. The graph shows that before the introduction of handle, the ROI was approaching 30% and when handle was introduced, the ROI increased to 46.05%. This increase is speculated to be as a result of increased acceptance of bottle water with handle. However, the ROI took a nose dive when the handle was removed to the tune of 34.41%. This is a 4.41% difference compared with the value before handle regime. This could be attributed to gain in market share which was not lost totally.

DISCUSSION

The design results as obtained shows that maximum deflection is 2.3282x 10^{-3}mm. Therefore, the deflection obtained is minimal, therefore is negligible. The maximum bending stress is $4.4677\text{x}10^5 N/m^2$ this indicates that the material can withstand the stress as the yield strength, S_y and ultimate tensile strength, S_u of steels are within the values $5.1\text{x}10^8 N/m^2$ and $7.1\text{x}10^8 N/m^2$ according to [10].

The cost of introducing handle was determined; also the difference in the Cost/mass was obtained between the foreign and locally made handle and presented in the table below.

It was presented that the difference in cost/mass ration is 0.3199N/g. This means that in every 50kg of handle, the bottled water company saves:

50000x0.3199 = ₦15995.

This amount of money saved is significant enough to encourage the bottled water companies in Nigeria.

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Comparing the responses of the locally and the foreign made handle

Table 4.5: Comparism of foreign and locally made handle responses

	Before Handle Regime (%)	**During Handle Regime (%)**	**After Handle Regime (%)**
Response of Locally Made Handle	29.69312176	46.3441641	34.41212559
Response of Foreign Made Handle	29.69312176	46.0466134	34.41212559

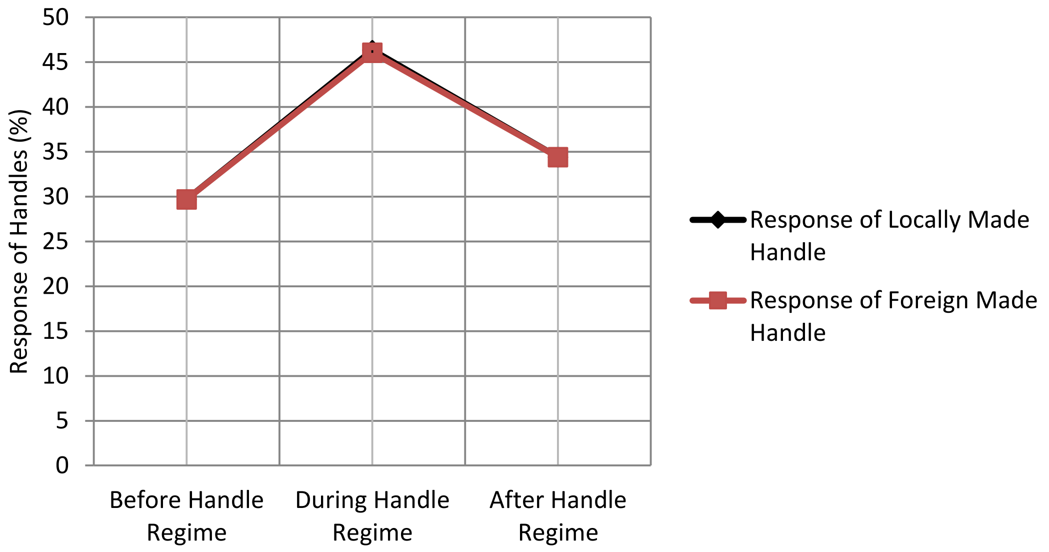

Figure 5.1: Comparing the responses of the locally and the Foreign Made Handle

The graph above represents the superimposition of the responses of the locally and Foreign Made Handle. The graph curves show that before the introduction of handle, the ROI was approaching 30% and when handle was introduced, the ROI increased to 46.34% and 46.05% for the locally and foreign made handles respectively. This 0.29% difference during the introduction of handle could be attributed to ₦0.9 (₦2.50-₦1.60) in foreign and locally made handle price. However, the ROI took a declined to 34.41% when the handle was removed in both cases though this is still higher than the response at the initial time before the introduction of handle. This is attributed to the fact that the company still retains some of the market share gained during the introduction of handle.

CONCLUSION

Having concluded the work, these observations, views and achievements were eminent. The design of a four cavity mould was possible with locally available materials. This was achieved and samples obtained. The samples obtained were tested and it was observed to compete favourably with the foreign. However, the sample obtained was seen to have less weight than the foreign handle. Also, the locally made handle was estimated to cost less than the foreign made handle which is a great saving to local bottled water manufacturing companies.

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The rate of return on investment was done and it was discovered that the two handles compared favourably. The rate of return was at the peak when the bottled water handle was introduced. This peak in rate of return was after a sharp change from a position it was before the introduction of handle to the peak position and another sharp turn downward after the introduction of handle.

This work should be seen as an engineering exercise involving a design and development covering aspects from tool design and manufacture, production and assessment of parts. This exercise aimed at a more precise description of the process and at helping the tool designers for injection moulding.

Specifically, in the strict context of this research work, a major contribution was given to the design of a tool. Thus, two major outcomes emerged from this work; an innovative injection mould with four cavity bottled water handle that can produce handles that will compete favourably or even serve as a replacement to the imported one.

As a result of this, the following conclusions are established and grouped according to the main objectives:

- Even though specialized machines may not be available; it is still possible to manufacture moulds locally with conventional machines.
- That convenience in carrying bottled water especially the 1.5ltr. size has been enhanced.
- That market share for bottled water industries is expected to increase due to public acceptability.

RECOMMENDATION

In the future, it is recommended that more work be done on the optimization of number of cavities for economic use of machines. Also, it is recommended that more research work be done to ascertain the acceptability of the product owning to the effect of the handle noticed on the company as reported in this work.

Therefore, we recommend that local plastic industries should embark on the production of bottled water handle for local consumption. Also, bottled water companies should patronize local manufacturers of bottled water handle at reduced cost.

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