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An Approach on Design Calculations of Plastic Water Container at Plastic Production Unit

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Abstract: Injection molding is one of the technique and methodology to create mold of various complex shapes with more detailed structure. The techniques involve various parameters to be checked for effective output. This should be done on design stage itself. We have come up some suggestion on how to approach an injection molding process. We have simplified design problems which may occur in the development phase of the product and solved in the design phase itself.
Keywords: Injection molding, product design, die design, cooling system.

I. INTRODUCTION

Injection molding is a process for producing parts of injecting material into mold. It is commonly used for making plastic materials such as thermosetting polymers, thermoplastic polymers glasses and elastomers. The problems to be solved in design phase which may occur in the development of the 3D model. Due to that we can avoid the rework in the design and modification in the design can be avoided. The design optimization gives the required level of dimensional accuracy, strength and reduces the time to design.

II. PHASE ONE: PRODUCT DESIGN

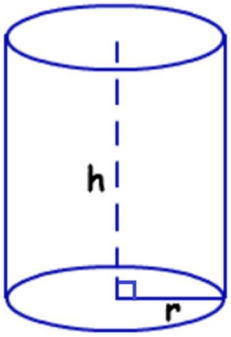
A. Selection Of Shape Of Water Container

We select shape of container is cylindrical because these shapes react to the stresses caused by internal pressures much more favourably. Because fluid pressure is same in all direction, a round wall shape will see even distribution of pressure, whereas any shape with corner will see concentrations of load due to pressure acting on either side of the corner pushing the two sides apart. So it's important to make them structurally simple, strong and reliable.

B. Dimensions Of Cylindrical Water Container

Geometrically cylindrical structure has largest volume capacity than any other shape used by the same material.
Demanded capacity of water in container is 2.2 litres.
Therefore volume of cylinder is given by, $V = \pi r^2 h$
Where, V = Volume of cylinder
r = Radius of cylinder
h = standard height of water
Now assume height,
h = 184mm (constraint by machine or die).
Capacity of container 2.2 litres converting in mm^3
2.2 x 1000 = 2200 mm^3
Volume of cylinder $(V) = \pi r^2 h$
$2200 = \pi r^2 184$
r = 63.14 mm

Figure 1



C. Material Selection

Selected material for water container PVC P20 $(C_2H_3Cl)_n$ (polyvinyl chloride) is the world's third-most widely produced synthetic plastic polymer, after polyethylene and polypropylene.
Some of the most significant properties of PVC are:

1) *Density:* PVC is very dense compact to most plastics (specific gravity 1.35- 1.4)
2) *Economics:* PVC is readily available and cheap.
3) *Hardness:* Rigid PVC is very hard.

4) *Strength:* Rigid PVC has extremely good tensile strength.
5) *Melting Point:* melting point of PVC is range very low 100ºc and higher value is 260ºc.
6) *Tensile strength:* Rigid PVC is 34-62MPa (4930-9000 PSI).

Now material use for product is PVC P20 has data found by pressure test.
Density is 1.32 g/cm^3
Poisson's ration is 0.42
Young's modulus is 2400 Mpa
Tensile yield strength is 28 Mpa
Tensile ultimate strength is 52 Mpa
So from above data we calculate wall thickness of cylinder
Wall thickness T_b, $T_b = \frac{pD}{2S_d}$
Where, p = Applied load
D = Diameter
$S_d = 0.8\ S_{yt}$
Now put all required data in given equation

$$T_b = \frac{0.2925 \times 2 \times 63.14}{2 \times 0.2 \times 0.352}$$

$$T_b = 0.26mm$$

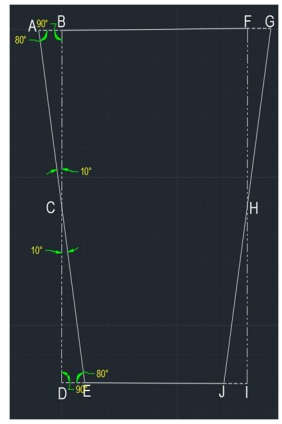


Figure 2

Shape of container is slightly tapered because of exterior appearance.
By figure 2, ΔABC and ΔCDE are similar by the AAA method and also because of side BC and side CD are same and side AC and side CE are same and angle of B and D are 90º.
Area covered by both the triangle is same so by this we conclude that there is no effect on capacity of container. So we are free to take a tapered shape of container.

D. *Water Passage and Handle*

For the removal of water from container with uniform direction or to specify the stream of water V shape passage is provided which has height up to 25mm to 29mm standard given by industry so assume 28mm and length is 21mm as per trigonometric calculation. Now looking towards the holding of water container handle is necessary so it design on the basis of balancing the weight of container. Total height of product is 210 mm so, 1st end of handle is from top 21mm and 2nd end is from top is 189 mm and height of handle is 168.32mm for handle shape consider I section of height of 12.12mm and thickness of 2.02mm.

III. PHASE TWO: DIE DESIGN

A. *General Consideration*

As per the product dimension die is same. Molten metal is liquid so it shrinkages thus shrinkage allowance is necessary to provide.
Therefore, value without shrinkage:
Volume = 2.624 x 10^6 mm^3
Surface area = 1.08 x 10^5 mm^2
Density = 1320 g/mm^3
To avoid the shrinkage we provide forceful injection of molten metal in to the cavity and maintain a constant pressure flow of the molten metal so that the hot molten metal gets poured easily.

B. *Following Are The Methods Of Calculation*

1) *Shot Capacity:* The maximum weight of molten resin that the injection molding machine can push out with one forward stroke is called shot capacity. The screw type machine is rated in term of volume of the injection cylinder (cm^3).

Shot capacity (w) = swept volume × ϱ × C
Where, ϱ = Density of plastic at normal temperature
C = 0.95 for amorphous plastics
(w) = 100 x 1.32 x 0.95
(w) = 125.4 gm

2) *Number of Cavities:* The number of cavities in injection moulds id determined in most cases by the machine performance, but sometime by the mold shape or the mold locking pressure. So, the shape of product is large thus it is not possible to create number of products at same die. It only allows making one product at one die.
3) *Plasticizing Capacity:* The rate by which polymer gets plastic/solid. The plasticizing capacity is expressed in kg/h of plasticized polystyrene.

a) Number of cavity is one
b) Plasticizing rate of material B (kg/h) x (p) = plasticizing rate of material A (kg/h) × $\frac{QA}{QB}$ Where, Q = total heat contain of plastic (j/kg)
A = polystyrene
B = material actually to be use (pvc) $\boldsymbol{p} = 40 \times \frac{239.4}{159.6}$
p = 60 kg/h

4) *Clamping Force:* The clamping force required to keep the mold during injection must exceed the force given by the product of injection pressure and of all impression, runners and gate. Lower clamping values can be used with these machines. Thinner sections need high injection pressure to fill and therefore require more clamping force. In case of screw injection machine 33 to 55% of injection pressure need only be considered maximum pressure can be obtained from machine manufacturing data sheet.

Determine clamping force with the help of number of cavities:
Formula:-

$$\boldsymbol{Nc} = \frac{c}{Pc \times Am}$$

Where, Nc = number of cavity = 1
c = rated clamping capacity (KN)
Pc = cavity pressure = 5012 psi
Am = projected area of molding including runner and spur
[Projected area of cavity (2718.24) + projected area of runner (6.03)]
Therefore, c = Nc x Pc x Am
c = 1 x 5012 x 2724.27
c = 13.65 x 10^3 KN

IV. COOLING SYSTEM

When it comes to injection molds, the importance of an efficient cooling system cannot be overemphasized. A reduction of just one to two second in cooling time can lead to as much as a 10-20% increase in the production rate. Saving time is not the only benefit of cooling system. Controlled cooling of the entire plastic part is vital to the preservation of its dimensional stability and mechanical properties. Properly cooled parts are less likely to warp, get stressed or be brittle. The cavity block and slides are the only components in the tool that require cooling lines. While the surrounding plates will get hot, adding cooling into them will not contribute much towards the ultimate goal of removing heat from the plastic part. In molds with individual cavity blocks, the cooling design typically can be viewed as a circuit. It will have an inlet and outlet, and will trace a path through the block. The circuit should be closer enough to the part to effectively remove the heat, but not so close as to risk drilling holes into any of the mold features.

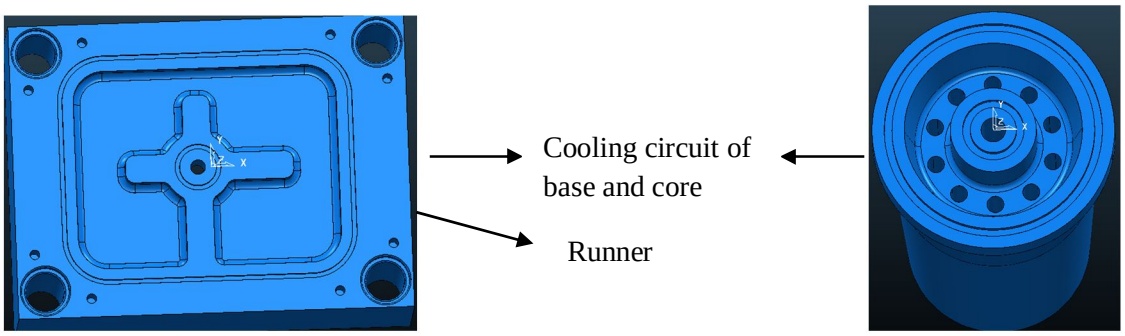


Figure 3: Base Plate

Figure 4: Core

Item like core pins and lifters are often too small to get any effective cooling inside them. Concerned about removing heat from small inserts, use material with a high rate of thermal conductivity for these component. Creating a water circuit with a thorough path around the part is the most important consideration for cooling effectiveness. Bending the circuit around the part contributes to a turbulent water flow, which helps to pull most of the heat from steel.

V. CONCLUSION

From the studying the above parameters and calculation we conclude it is possible to design a water container and die of this product on CAD software. Injection mold is properly designed and all possible solutions are considered which can solve the problem, are generated during the design and production time. We study the cooling condition and geometrical design of the product.

VI. RESULT

By calculating the geometry of product and important parameters of die we can successfully design the product and die of product on CAD designing software.

We also found that all the assumed as well as theoretical values calculated match the actual values calculated on product dimensions. Thus we can say that our calculations are under safe limits.

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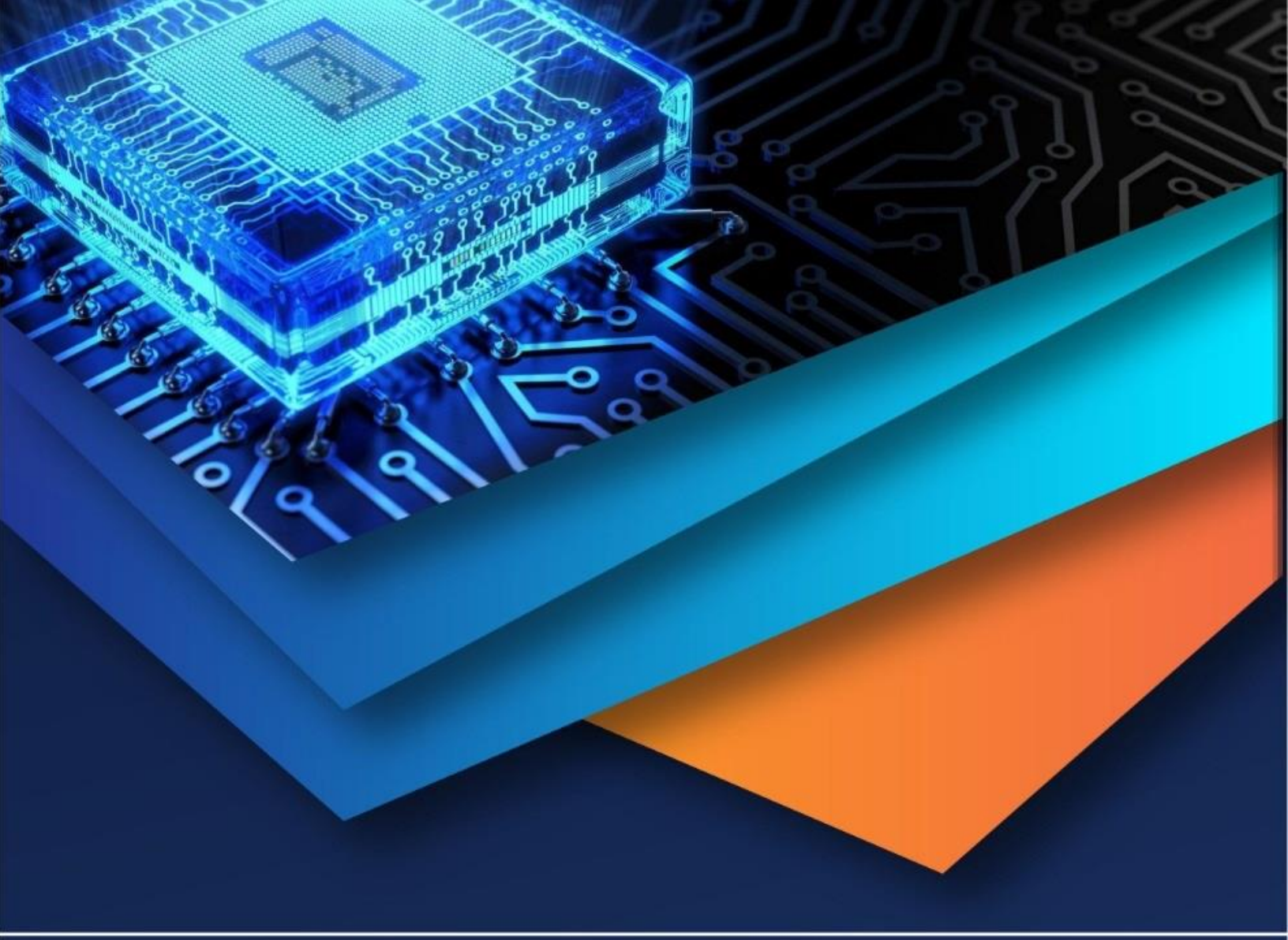

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