Development of Vacuum Forming Machine

Mr. Sanket durafe, Mr. Vijay Phatangade, Mr. Sagar Irole ,Mr.Sagar Bangar

Abstract— In this process, the vacuum pressure is used to form the heated thermoplastic sheet into the desired shape. The thermoplastic sheet is placed on the mold surface and fixed with the help of clamping unit. The sheet is heated until it is softens and thereafter vacuum needs to be applied quickly. A surge tank is used to quickly pull the air out between the mold cavity and the sheet. The frame is heated and slowly moved toward the mould until the frame touches the bottom of the chamber and the soft plastic is draped over the mould. When the vacuum is created, the sheet conforms to the shape of the mold cavity. The formed part is cooled and then ejected from the mold cavity vacuum-forming is an industrial technique used for batch production or mass production. This process enables thermoplastics to be formed into complicated shapes such as packaging, storage trays and seed trays.

Key words-mold, Thermoforming, vacuum.

I.INTRODUCTION

Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product. The sheet, or "film" when referring to thinner gauges and certain material types, is heated in an oven to a high-enough temperature that permits it to be stretched into or onto a mold and cooled to a finished shape.. Its simplified version is forming. In its simplest form, a small tabletop or lab size machine can be used to heat small cut sections of plastic sheet and stretch it over a mold using vacuum This method is often used for sample and prototype parts. In complex and high-volume applications, very large production machines are utilized to heat and form the plastic sheet and trim the formed parts from the sheet in a continuous high-speed process, and can produce many thousands of finished parts per hour depending on the machine and mold size and the size of the parts being formed. Thermoforming differs from injection molding, blow molding, rotational molding and other forms of processing plastics. Thin-gauge thermoforming is primarily the manufacture of disposable cups, containers, lids, trays, blisters, clamshells, and other products for the food, medical, and general retail industries. Thick-gauge thermoforming includes parts as diverse as vehicle door and dash panels, refrigerator liners, utility vehicle beds, and plastic pallets. In the most common method of high-volume, continuous thermoforming of thin-gauge products, plastic sheet is fed from a roll or from an extruder into a set of indexing chains that incorporate pins, or spikes, that pierce the sheet and transport it through an oven for heating to forming temperature. The heated sheet then indexes into a form station where a mating mold and pressure-box close on the sheet, with vacuum then applied to remove trapped air and to pull the material into or onto the mold along with pressurized air to form the plastic to the detailed shape of the mold. (Plug-assists are typically used in addition to vacuum in the case of taller, deeper-draw formed parts in order to provide the needed material distribution and thicknesses in the finished parts.) After a short form cycle, a burst of reverse air pressure is actuated from the vacuum side of the mold as the form tooling opens, commonly referred to as air-eject, to break the vacuum and assist the formed parts off of, or out of, the mold. A stripper plate may also be utilized on the mold as it opens for ejection of more detailed parts or those with negative-draft, undercut areas. The sheet containing the formed parts then indexes into a trim station on the same machine, where a die cuts the parts from the remaining sheet web, or indexes into a separate trim press where the formed parts are trimmed. The sheet web remaining after the formed parts are trimmed is typically wound onto a take-up reel or fed into an inline granulator for recycling. There are mainly three different types of thermoforming process depending upon the pressure required i.e., vacuum forming, pressure forming and matched die forming.

Pressure Forming -The pressure forming process is closely related to vacuum forming. In this process, the air pressure required is much higher as compared to the vacuum forming. The preheated plastic sheet is placed on the mold surface. The high pressure is developed in between the softened sheet and the pressure box. Due to high pressure, the preheated plastic sheet can be deformed into the mold cavity in a fraction of a second. The formed sheet is held in the mold cavity for cooling for a few seconds. The formed part thereby solidifies and is ejected from mold cavity. Prototype

Matched die Forming -Matched die forming is also called mechanical forming. In this process, mold consists of two parts. The thermoplastic sheet is heated with the application of heat until it softeners. The preheated sheet is placed into the mold surface (that is called die) and through punch pressure is applied on the hot sheet. The air in between the die and softened sheet is evacuated by using vacuum pump, and therefore the thermoplastic sheet conforms to the mold shape. The formed

Vacuum Forming-In this process, the vacuum pressure is used to form the heated thermoplastic sheet into the desired shape. The thermoplastic sheet is placed on the mold surface and fixed with the help of clamping unit. The sheet is heated until it is softens and thereafter vacuum needs to be applied quickly. A surge tank is used to quickly pull the air out between the mold cavity and the sheet.

The frame is heated and slowly moved toward the mould until the frame touches the bottom of the chamber and the soft plastic is draped over the mould. When the vacuum is created, the sheet conforms to the shape of the mold cavity. The formed part is cooled and then ejected from the mold cavity vacuum-forming is an industrial technique used for batch production or mass production. This process enables thermoplastics to be formed into complicated shapes such as packaging, storage trays and seed trays.

II.COMPONENT OF VACUUM FORMING MACHINE

1)The Heater System (Halogen tubes 12") –Ceramic heater having high thermal mass.so required more time for heating ,because of this Halogen tubes 12"because he give Power for Heating - 6000 watt (4 no tubes 1500 watt each)which means they required less time for heating.

2) Heat Zones(Wooden frame)-Heat output increased in zones where definition is poor. Because of this we use Plastic sheet holder of Wooden material .this give us effective result in heat zone.

Fig, Heat zone

3) The Vacuum System(Air compresor)- vacuum pump are used for generating vacuum but it is so costly, most of the time it give off vapour when they are heated so its causes corrosion, and reduces performance and ultimately failure because of this we use air compressor for sucking air from one side so that it create vacuum in vacuum chamber.

Fig Air compressor

4) Other Component -For proper working of vacuum forming process we required other components like Tubes - Polyamide & Plastic, Mold/ die–Wooden, Electrical connection–Standard. These components plays vary important role like sucking air from suction chamber, giving support to plastic sheet, supply the power. Alternatively, you can construct a simple hot box using plywood and a low power heater such as a greenhouse heater or even light bulbs

Fig. Tubes-Polyamide & Plastic and Die for vacuum forming

5)Plastic Sheet (PVC or PU plastic sheet)-A plastic sheet is heated to applicable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product so that we can use PVC or PU plastic sheet for vacuum forming. This sheet gives us required ductility, strengths after heating a sheet in vacuum forming machine.

Fig . Plastic sheet

6) The Platen System- Lifting the platen as quickly as possible so that forming takes place before the sheet begins to cool and go rigid. Because of this we use gas cylinder for easy lifting and giving support. So it is easy to handle the equipment. Bigger machines need pneumatic, hydraulic or other mechanical systems because they have bigger, heavier moulds and bigger, thicker sheets which offer more resistance. Because of this we use gas cylinder for easy lifting and giving support. So it is easy to handle the equipment.

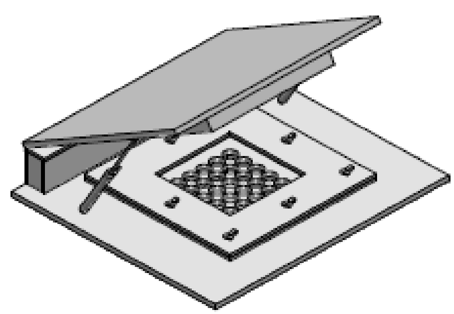

Fig. Platen system

III.Material Selection

Sr. No	Components Name	Material selection
1	Base frame	mild steel (Painted)
2	Vaccum chamber	Wooden
3	Plastic sheet holder	Wooden
4	forming material	PVC or PU sheet
5	Heating source	Halogen tubes 12"
6	Compressor	Standard Material (Plastic body)
7	Tubes	Polyamide & Plastic
8	Mold/ die	Wooden
9	Electrical connection	Standard
10	Power for Heating	6000 watt (4 no tubes 1500 watt each)

Table .Material Selection

IV.WORKING OF VACUUM FORMING MACHINE

1) The sheets are clamped in place on a heat proof air-tight seal.
2) The heater system moves over the sheet,and begins heating.
3) Once the sheet has reached it‘s thermoforming temperature the vacuum pump is energized.
4) The heater moves back to it‘s resting position or the sheet moves from the heating position to the moulding position.
5) The mould, mounted on a moving platen, moves up into the sheet which drapes over it.
6) Once the platen reaches the top of it‘s stroke, the space between the underside of the sheet and the upper surface of the mould forms an air-tight pocket connected to the vacuum pump, which then pumps air from between the two.
7) This removes air which is preventing atmospheric pressure from pushing the sheet down over the mould.
8) As the sheet cools it contracts, gripping the mould. Hencethe next step is to reverse the airflow, using air pressure to force the forming off the mould and prevent it sticking, this step has become known as the _blow cycle‘. Blow cycles are short - just long enough for the forming to release from the mould and immediately followed by another vacuum cycle.
9) Vacuum/blow cycling continues until the sheet is rigid once more. At this time, the vacuum is switched off or the mould lowered and the forming is released from the clamp.

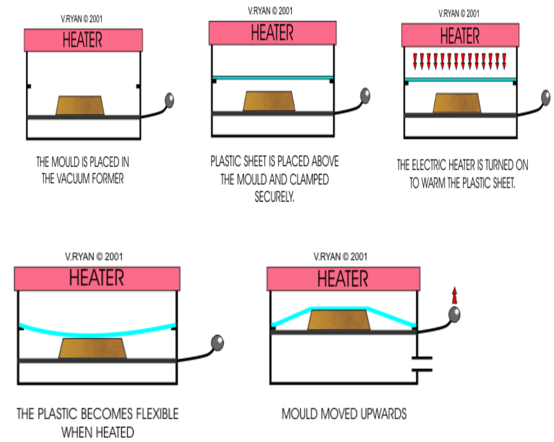

Fig working of vacuum forming

V.Design Calculation

The specs along with the drawing for this component are given below:
Component Name –Wooden Die Thickness – 0,5 +/- 0.03 mm
Developed Blank Length (L0) & Blank Width L0 = square (300^2+300^2) = 424.24 mm
B0 = 300+300+40+300+40
= 980 +75mm (as draw bead)
= 1050 mm

1)Draw Ratio-The draw ratio expresses the relationship between the beginning surface area of the unformed sheet which covers the opening of a feature, and the ending surface area of the interior of the feature once formed. A 3 to 1 ratio is generally a maximum draw ratio. Avoid multiple tall features too close to each other. Generally, the distance between two features, like ribs or cooling vents, needs to be no less than 2x the material thickness.
At this component, the Draw Ratio = H /d
= 40 /300 = 0.1333
The draw is simple & may require only one stage for completion because 0.133 is less than 0.75 Material& die clearance.
Calculation formula for finding out the clearance between the Die and material clearance for the dee

2)Drawing process.
C= T+ k (10 T)
Where,
C = Clearance
T = Material Thickness
k = Coefficient (for aluminium alloy =0.25 grade) T = 0.5mm
$C = 0.5 + 0.25(\sqrt{10 * 0.4}) = 1$ mm
Clearance between material and Die, C = 1 mm.

3)Draw Force
Draw Force can be calculated by empirical relation, P =[2(Li+Bi)*t+S{(Lo+bo/Li+Bi)-C}]
Where,

P = Draw Force in N.
Li = Final part length in mm=300 mm Bi = Final part width in mm= 300 mm Lo = Blank length in mm=250 mm Bo = Blank width in mm= 250 mm
t = Thickness of Metal in mm = 0.5 mm
S = Shear strength of Metal in N/mm2 = 40 N/mm2 C = Constant (Take 0.6 to 0.7)
We know,
P = [2(Li+Bi)*t +S{(Lo+bo/Li+Bi)-C}]
= [2(300+300)*40+40{(424.24+1050/300+300)-0.7}]
=1.27 KN
Factor of safety should be taken as 15%
Therefore, Draw Force (P) = $(1.2*10^{3)}$ / 1.15= 1.1043 KN
4)Die Block Dimension -Die block Dimension -300 mm X 300 mm Thickness for die should 40 to 50 mm (Take 40 mm)
5)Blank Holding Force -

Blank Holding Force (H.F.) is always 25 % of Draw Force, Therefore ,B.H.F. can be calculated as,
Blank Holding Force (B.H.F.) = 30 % of Draw Force
1) 30 % *1.27*10^3
2) 1.65 KN Material for Blank Holder should be used.
6)Calculation of PVC material
To Calculate Forming Stress
$\sigma_f = k\varepsilon$
where,
ε = is maximum strain during deformation process n= is strain hardening exponent(0.1)
σ = forming stress
$\sigma_f = 30*4^{0.1}$
= 34.46 N/mm^2
Forming Stress = 34.46 N/mm^2
Normal Stress = Force/Area
34.46 = Force / (250*250)
= $2.153*10^6$ N
Force = $2.153*10^6$ N
7)Normal Pressure = Force / Area
= $2.153*10^6$ / (250*250 Normal Pressure = 3.45 Bar

VI.ADVANTAGES
(1)In less time more production rate can achieve .
(2)Rapid prototype development.
(3)Low initial costs.
(4)Low operating cost .
(5)Less thermal stresses are present compare to injection moulding and compression moulding.
(6) Dimensional stability comparatively good.
(7)Skill operator are not required .

VII.DISADVANTAGES
(1)Maintenance should be required time to time,
(2) Factor of safety during heating and vacuum forming is so important.

VIII.CONCLUSION
We conclude that comparatively other production process vacuum forming process is simple, fast, low costly and effective. It reduces electric power for plastic heating, it also increasing the quality , yield of product and production rate .so it save the energy.Important factor is that it increases plastic forming speed.

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