International Journal of Engineering Research And Advanced Technology (IJERAT)
ISSN: 2454-6135 **[Special Volume. 02 Issue.01, May-2016]**

DESIGN, ANALYSIS AND MANUFACTURING OF THERMOFORMING TOOL FOR DISPOSAL CUPS

AMEENA TAHERA[1] , T.J.JITENDRA[2]

[1]STUDENT,M TECH (PDM),Department of Industrial Engineering and Management,

JSS Academy of technical Education, VTU, Bangalore, Karnataka, India.

[2]Assistant professor, Department of Industrial Engineering and Management,

JSS Academy of technical Education,VTU,Bangalore,Karnataka,India

ABSTRACT

Thermoforming molding continues to be one of the advantageous manufacturing processes to produce components with geometrical intricacies and is also for mass production of components made of typical engineering plastic materials. This dissertation work deals with Design, Analysis and Manufacturing of Thermoforming tool for the component DISPOSABLE CUP. The main task of this project is to produce eleven components in one shot, employing through thermoforming molding technique by providing the various design factors on a new concept for the same. Material for this component is Polystyrene. This design details or design considerations in thermoforming molding including shrinkage, ejection, cooling system etc.,

Keywords: *Thermoforming, design.*

---

1. INTRODUCTION

Thermoforming is one of many manufacturing process that converts plastic resin into usable everyday product. Thermoforming is considered to be one of the most cost-effective processes in plastic manufacturing because of the low molding costs and fast molding cycles. Speed and cost efficiency are the highlighted qualities that thermoforming offers which lead the way for the process becoming so important in industry today.

We have entered into another area of plastic consumer goods, which are continuously replacing the traditional items. The use of disposable items is increasing day by day because of growing hygiene consciousness, low cost, easy usability and impressive appearance. The major products that are in use are disposable glasses, cups, plates and spoons. These have become a part of the hectic life style due to their convenience.

The main advantage of these plastic cups is that they are completely leak proof. Plastic cups can be made up of different sizes and they can hold bulk material easily in comparison to the traditional paper cups.

2. PROCESS

Thermoforming is the process of heating plastic sheet to a pliable state and forming it into shape. Thermoforming offers processing advantages over injection molding and blow molding, which include lower pressures, lower mold costs, production of multilayer structures, and ease of fabrication of large parts. By using a multi cavity tool, smaller, thin wall parts, such as those used for food packaging, can be formed in large volume with relatively short cycle time.

Thermoforming is a process of shaping flat thermoplastic sheet which includes two stages: softening the sheet by heating, followed by forming it in the mold cavity.

The key advantages of thermoforming include:

- Sharp detail.
- Tight tolerances.
- Flexible tooling and engineering.
- Efficient set-up.

3. MATERIALS

Thermoplastics which may be processed by the thermoforming method are:

- Polystyrene (PS)
- High Impact Polystyrene(HIPS)
- Poly Carbonate(PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Acrylo nitrile-Butadiene-Styrene (ABS)

Table 2.1 Transition Temperatures of Some Thermoformable Polymers

Polymer	Glass Transition Temperature		Melting Temperature		Heat Distortion Temperature 66 lb/in^2 or 0.46 N/mm^2	
	[°F]	[°C]	[°F]	[°C]	[°F]	[°C]
Polystyrene	200	94	–	–	155–204	68–96
PMMA	212	100	–	–	165–235	74–113
PMMA/PVC	221	105	–	–	177	81
ABS	190–248	88–120	–	–	170–235	77–113
Polycarbonate	300	150	–	–	280	138
Rigid PVC	170	77	–	–	135–180	57–82
PETG	180	82	–	–	158	70
LDPE	−13	−25	239	115	104–112	40–44
HDPE	−166	−100	273	134	175–196	79–91
Cellulose acetate	158,212	70,100	445	230	125–200	52–93
Polypropylene	41	5	334	168	225–250	107–121
Co-Polypropylene	−4	−20	302–347	150–175	185–220	85–104
PET	158	70	490	255	120	49

4. APPLICATION OF THERMOFORMING

Thermoforming is widely used in the food packaging industry for manufacturing ice cream and margarine tubs, meat trays microwave containers, snack tubs sandwich packs etc.

Thermoforming is also used for manufacturing some pharmaceutical and electronic articles, small tools, fasteners, toys, boat hulls, blister and skin packs. Thermoforming is commonly used for food packaging, but has many applications from plastic toys to aircraft windscreens to cafeteria trays. Thin-gauge (less than 0.060 inches) sheets are mostly used for rigid or disposable packaging, while thick-gauge (greater than 0.120 inches) sheets are typically used for cosmetic permanent surfaces on automobiles, shower enclosures, and electronic equipment.

5. FACTORS THAT CAN AFFECT MOLD DESIGN

Mold design involves several key factors, including

- Draft Angle – Minimum draft angle should be two to three degrees on a male mold and one-half to one degree on a female mold. Molds with textured surfaces may need more draft so the part will release without scratching.
- Shrinkage – Molds must be made oversized to allow for shrinkage. Usually, an allowance of 0.003-0.005 in. /in. (cm/cm) on male molds and 0.005-0.006 in. /in. (cm. /cm.) on female molds is adequate. The material, its coefficient of thermal expansion, and part design all affect shrinkage.
- Radii – Radii on ribs and fillets should not be less than the minimum part thickness. The radii should be as much as four times the wall thickness in areas of high loading or where extra stiffness is required.

- Cooling system- Uneven temperature of the mould surface results uneven shrinkage in parts with molded in stresses, warped sections, sink marks, poor surface appearance and varying part dimensions from cycle to cycle and even cavity to cavity.

6. METHODOLOGY

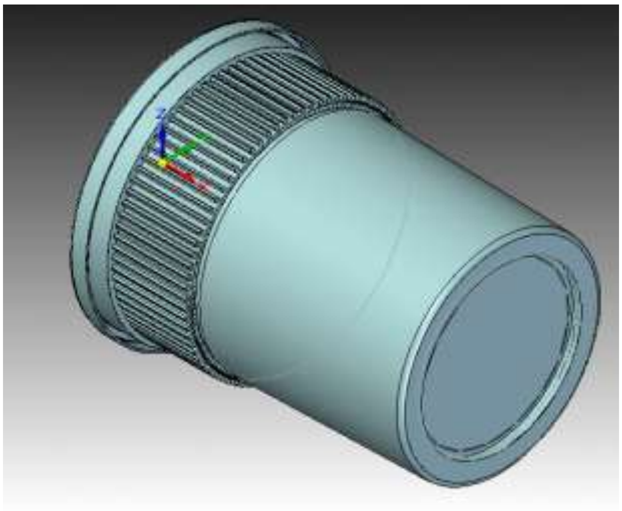
The specific Methodology of project is the systematic step-by-step planning approach in designing a complete thermoforming tool includes following steps in general.

1. Component Study.
2. Solid Modeling of the Component.
3. Tool Design.
4. Selection of Tooling Material.
5. Analysis of the cavity back plate.
6. Tool manufacturing.
7. Tool Assembly and Tryout.
8. Cost Estimation of the Tool.

7. SOLID MODELING OF COMPONENT

This was done employing 3D Geometry Software (SOLID EDGE ST2). This software is having tools to perform the operations like extrude, cut, sweep etc. and is also having tools to assemble parts modeled with suitable constraint.

Creating the assembly helps to check a prior possibility of interference between mating parts, create 2D drawings and detailing.



8. TOOL DESIGN

In this section step by step approach to the design of thermoforming tool is set based on experience, empiricism and expertise and few design calculation.

8.1 SELECTION OF TOOLING MATERIALS

Selection of tooling materials: The steel used in the manufacture of mould varies depending on the applications. Proper material selection and proper combination of alloys in varying percentages are required for finished moulds. Characteristics of polishing ability, high dimensional stability and harden ability are directly introduced to the alloy steel.

8.2 STRUCTURAL ANALYSIS OF CAVITY BACK PLATE

The Static Structural Analysis was carried out by Ansys Workbench V_{12} on the cavity back plate in order to determine the Total deformation as this plate is likely to deform on prolonged usage due to the application of backward force from the ejector rod by pneumatic pressure which is about 49N. The 3D part of the model was made in Solid edge ST2 and then converted into IGES format in order to import it into Ansys Workbench $V_{12.}$

8.3 TOOL ASSEMBLY AND TRYOUT

Tool tryout and troubleshooting: After the tool is manufactured and assembled, the tool is ‘tried’ to see that component produced is true to the geometry and dimensions specified by the customer. Tryout is a procedure where the tool is subjected to actual working condition and the performance of the tool is noted. After the tool has been tried out, the component is thoroughly inspected for various defects. If any defects are found, it is suitably reworked.

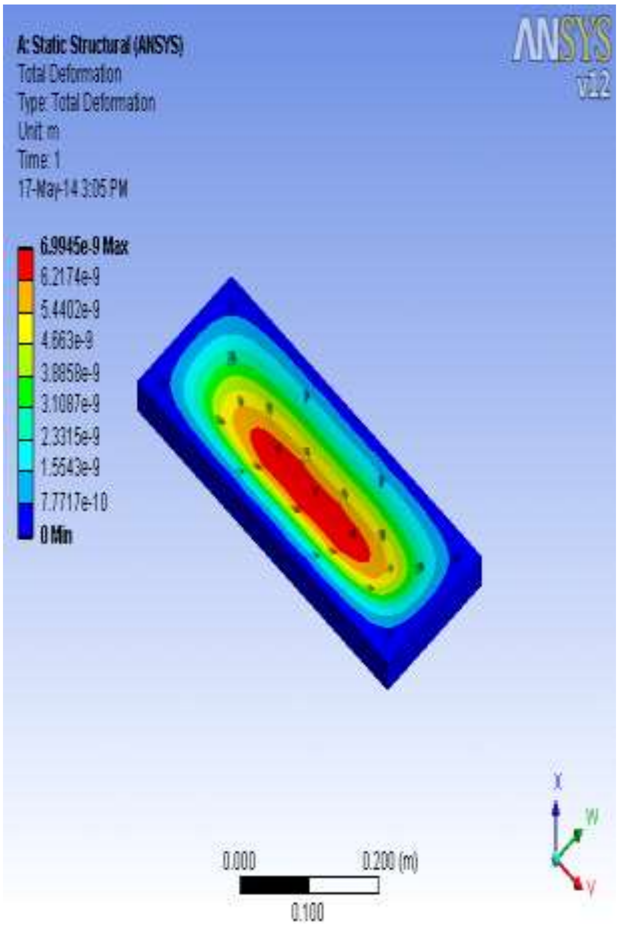
8.4 COST ESTIMATION

Tool cost estimation is also one of the integral parts of this methodology. Tool cost has to correspond with the life cycle, production, productivity and quality aspects in the manufacture of components and hence, its importance in the tool designs exercise.

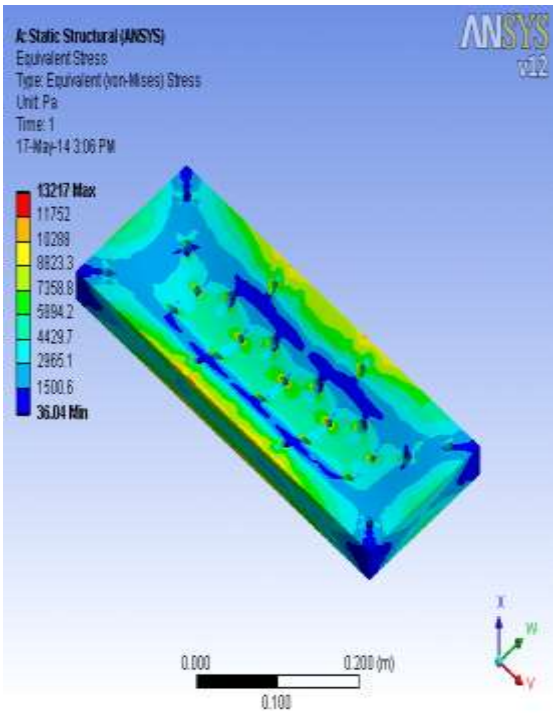
On large parts, thermoform tooling can be dramatically less expensive than injection molding tools. For this reason, thermoforming, particularly pressure forming, is the more cost effective choice for very large, thin-walled parts.

8.5 CAVITY BACK PLATE ANALYSIS

Total deformation



Equivalent stress



9. CONCLUSION

Thermoforming tool analysis is very important because tool can manufacture components up to 40,000 to 50,000 per shift. If tool get deformed or break down until the part is replaced the production stops. The following conclusions were made:

1. The cavity back Plate is one of the major components of the thermoforming tool which is subjected to a lot of force under each stroke, this leads to deformation of the tool under prolonged.

2. The deformation can be reduced by increasing the thickness of the Cavity Back Plate up to 26mm.

10. TOOL DESIGN COST

Cost estimation may be defined as the process of forecasting the expenses that must be incurred to manufacture a product. These expenses take into consideration all expenditures involved in design and manufacturing with all the related service facilities such as pattern making, tool making as well as portion of the general administrative and selling costs. Cost estimates are the joint product of the engineer and the cost accountant.

The tool design cost varies from one tool to another as well as one tool type to another. However the general recommendations for purpose of estimation are

- For simple Thermoforming tool – 3% of tool cost.
- Complicated Thermoforming tool – 7% of tool cost.

10.1 FUNCTIONS OF COST ESTIMATING

- To calculate the cost of new material needed to manufacture a product.
- To find the cost of parts to be purchased from outside vendors.
- To determine the most economical process, tooling or material for making a product.
- To establish a standard of performance at the start of project.
- For feasibility studies on possible new products.
- To calculate the direct and indirect labor cost associated with the manufacture of the product, based upon work study.
- To calculate various overhead charges associated with the product.

11.CONCLUSION

The main objective was to Design, analysis and manufacture of thermoforming tool to produce the component (disposable glass) which is free from defects and meet the specified tolerance limits. The Design and manufacturing of the thermoforming tool was completed with the required standards and quality set by the organization.

The tool design process involved design of various thermoforming elements such as housing plates, etc.

The design of the thermoforming mould tool was completed with the required standards and quality set by the organization. The components produced have been successfully used in the assembly with the mating part.

Tool cost estimation of the thermoforming mould tool suggested that the tool was financially feasible and acceptable by the organization. Finally the tool was manufactured using the in-house tool room facilities according to standards specified by the organization. The manufactured mould elements were then assembled. Trial out of the thermoforming mould tool revealed that components obtained were satisfactory. Hence the design and manufacturing of the thermoforming mould tool for the components is successful.

REFERENCES

1. **Novotny, P., Kouba, K, Perdikoulias, J.** and **Saha, P.,** "Optimization of Thermo-forming"; *ANTEC* (1999).

2. **Hegemann, B., Tessier, N.,** and **Bush, T.** "Various Plug Assist Materials and Their Effect on the Thermoforming Characteristics of Polymer Sheet", *Thermoforming Quarterly, Fourth Quarter* (2002), **Vol. 21**, **Number 4**, pp 12-16.

3. **Martin, N. J., Lappin, J. F., Harkin-Jones, E. M. A.,** and **Martin, P. J**.; "The Use of Hot Impact Testing in the Simulation of the Plug-Assisted, Thermoforming Process", School of Mechanical and Manufacturing Engineering The Queens University of Belfast. Belfast, Northern Ireland, *ANTEC* (2000).

4. **Lapping J. F., Harkin-Jones E. M. A.,** and **Martin, P. J.** "Investigation of Heat Transfer in the Plug Assisted Thermoforming Process", Collins School of Mechanical and Manufacturing Engineering The Queens University of Belfast, Belfast Northern Ireland, , *ANTEC* (2000).