Novateur Publication's
International Journal of Innovation in Engineering, Research and Technology [IJIERT]
ICITDCEME'15 Conference Proceedings
ISSN No - 2394-3696

DESIGN OF INNER LID OF PRESSURE COOKER WITH CIRCULAR SHAPE HAVING STRAIGHT EDGES

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ABSTRACT
Pressure cooker works hand in hand with the working woman. This is happening because of saving in time & energy. It means that pressure cooker become the inevitable item in kitchen. If we concentrate on the analysis of inner lid of the pressure cooker, it is highly beneficial for everyone. That is why we concentrate on the possible shapes of lids of pressure cooker. The existing pressure cooker is of two type i. e. inner lid and outer lid type. The shape of existing inner lid pressure cooker is generally having elliptical shape. This shape is because of locking & easy handling. The different alternatives are arising. Out of which the best alternative found is the circular shape having straight edges at the edges. The modification suggested here is also serving the same purposes as like the previous one. The advantages obtained here are also giving better result for locking, increase the heat transfer area & saving in cooling time for food in measurable way as compare with the elliptical inner lid pressure cooker. The result obtained will be definitely good comparing with the old model. Here simple & thermal stress analysis had been done by finite element method for the load & temperature stability.
KEYWORDS: Pressure cooker, elliptical inner lid, modified inner lid

INTRODUCTION

Any vessel which operates under pressure or in which the pressure more than atmospheric is maintained, can be called as pressure vessel. In the pressure cooker also inside pressure is higher than atmospheric pressure. So pressure cooker is a type of pressure vessel in which water is heated up to 100°C. When water reaches to a 120°C, steam is formed. This steam exerts pressure internally on the lid. Because of which stresses are formed in the lid material.

The vessel used may be cylindrical or spherical. Though the spherical vessel is better in strength & lowers in cost, cylindrical vessel is commonly used due to difficulties in fabrication.

Due to the internal pressure, the various stresses induced in the vessel are:

i) Hoop stress or circumferential stress
ii) Longitudinal stress
iii) Radial stress

1) ABOUT PRESSURE COOKER

Pressure cookers are generally made from Aluminum or Stainless steel. The former may be stamped & buffed or anodized, but this metal is unsuitable for dishwasher. Higher quality steel pressure cookers are made with heavy, three-ply or copper clad bottom (heat spreader) for uniform heating, since stainless steel has lower thermal conductivity. Most modern units are dish washer safe although some manufacturer may recommend washing by haws. A gasket or sealing ring forms a gas tight seal which does not allow the air or steam to escape between the pot & the lid. Normally when more pressure has built up inside the pressure cooker, only one way for escaping the steam is through a regulator. In case the regulator is blocked, a safety valve is provided as a backup escape route for steam. The simplest safety valve is a loose lifting rubber plug in the lid held in place by steam pressure. If the pressure exceeds the design limits, the plug pops out of its seat.

2) MODIFICATION IN INNER LID OF PRESSURE COOKER

Pressure cookers are of Inner lid pressure cooker & Outer lid pressure cooker. The existing inner lid of the pressure cooker is having the elliptical shape. In this elliptical shape, the lid is inserted in the pressure vessel by turning it by the minor axis & returning it to original position so that major axes of pressure vessel pot & lid are

matched. If we change the lids shape to circular having straight portion at the joint, what will happen? For which first we have to determine the areas of existing & modified inner lid of pressure cooker. Then determine the amount of heat transfer in both the cases. We observed that time required for heat dissipation is less than the existing. Because of this modification, advantages obtained are as follow

a) Increase in Heat transfer area.
b) Reduced in waiting time for cooling.
c) Easier Handling of inner pots.

DESIGN OF INNER LID OF PRESSURE COOKER

Most of the existing pressure cookers are of inner lid type. The lid & pressure vessel of pressure cooker is having the elliptical shape. Here maximum attention is on the modification in the shape of inner lid of pressure cooker. The existing inner lid is of elliptical shape. In this elliptical lid is inserted in the pressure vessel pot by turning lid from minor axis of vessel up to matching major axes of both. Instead of elliptical lid as in figure 1, the suggested modification in the inner lid shape as circular shape having straight edges at the circumference as shown in figure 2.

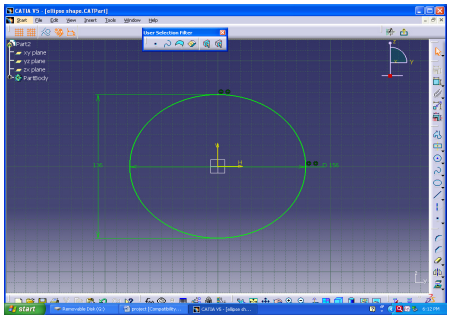


Fig. 1 - Elliptical Lid Shape

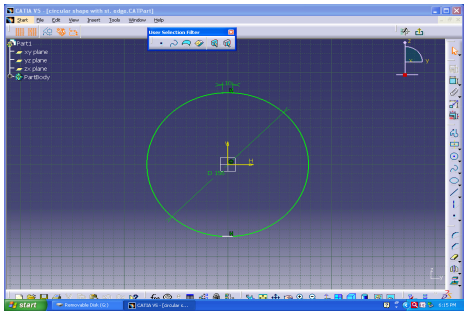


Fig. 2 –Circular Shape with St. Edges

The new shape also follows locking of pressure cooker. Here also the major axis of pressure vessel matches with minor axis of lid during locking. This locking is due to the difference in dimensions. In order to locking, the existing shape of the inner lid & pressure vessel pot of pressure cooker can be reshaped into circular shape having straight edges at two opposite location on the circumference as in figure 2.

For modeling we are using CATIA V5, as it is a leading product development solution for manufacturing organization of all sizes. CATIA V5 means computer aided 3D interactive application version 5. Apply its capabilities to a variety of industries such as aerospace automobile, industrial machinery, electrical, electronics, shipbuilding, plant design & consumer goods. It provides an integrated suite of CAD, CAE, CAM application for digital product definition & simulation. By this software, in modeling the original & modified inner lid shapes are as shown in figures 03 &04 respectively.

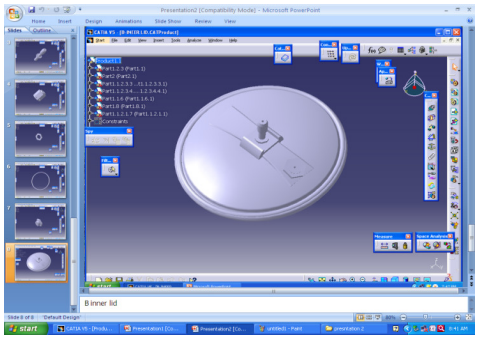


Fig.03: Original inner lid

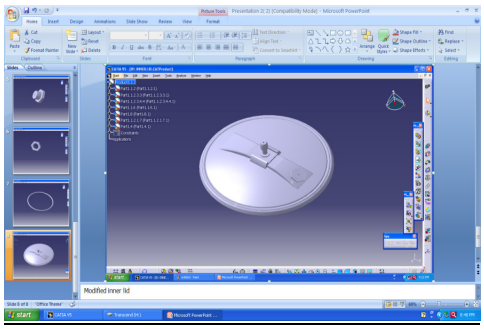


Fig. 04: Modified inner lid

For the sample calculation & analysis consider the pressure cooker of capacity of 2.5 liters.

- **INCREASE IN AREA**

The existing shape of inner lid of pressure cooker of 2.5 liters is elliptical whose dimensions by measurement are as shown in figure 01 i. e.

Length of major axis = 156 mm
Length of minor axis = 136 mm

Area of elliptical inner lid = $\pi \times a \times b$

Where a = major axis /2 =156/2 =78 mm
b = minor axis /2 =136/2=68 mm

$A_{elliptical} = \pi \times 78 \times 68$
$= 16650 \text{ mm}^2$

The modified shape of inner lid of same pressure cooker is circular inner lid with straight edges at edges circumference are as shown in figure 02

Diameter of circular portion = 156 mm
Length of straight edge = 10 mm

Area of circular inner lid with straight edges = $A_1 - A_2$ ---------- (1)

Where A_1= Area of Circular Shape
A_2= Area of two chord at straight edges

Area of Circular Shape = A_1
$= \pi \times (156/2)^2$
$= 19113.44 \text{ mm}^2$

Area of two chord at straight edges = A_2
$= 2\times [r^2/2(\pi \times \theta/180^\circ - \sin\theta)]$
Where r = radius of circular part = 156/2=78 mm
θ = angle subtended by straight at centre of lid= 20 $^\circ$
$= 2\times [78^2/2(\pi \times 20^\circ/180^\circ - \sin 20^\circ)]$
$= 42.58$ mm

Put in eq^n (1)

Area of circular inner lid with straight edges =19113.44 - 42.58
$= 19070.86 \text{ mm}^2 \approx 19071 \text{ mm}^2$

Increased in area due to modification = $A_{advantage}$
$= A_{modified} - A_{elliptical}$
$= 19071 - 16650$
$= 2421 \text{ mm}^2$

% **Increase in area** = (19071-16650) ÷ 16650 × 100
= 14.54 %

This much amount of extra opening is available for blowing of steam to atmosphere, as compare with elliptical shape.

- **INCREASE IN HEAT TRANSFER AREA**

By this, more 14.54% area is available for heat dissipation from food to the atmosphere through new modified opening of pressure vessel pot after removing inner lid after cooking food

Amount of heat dissipated per unit length is given by

$Q = h A\Delta T$

Where

h= Convective heat transfer coefficient of material
A=Area through with heat is passing
ΔT= Temperature difference

Here h, ΔT is constant for both lids, as the material is same, so only variable remaining is area i. e. A. Hence Amount of heat dissipated per unit length is directly proportional to Area of inner lid of the pressure cooker.

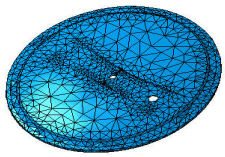
In the original inner lid having elliptical shape, the area is 16650 mm^2 & the modified inner lid having the circular shape with the straight edges at the circumference, the area is 19071 mm^2. Therefore 2421 mm^2 more area is available for heat transfer from the food to the atmosphere due to change in shape of inner lid of pressure cooker.

THERMAL STRESS ANALYSIS OF ORIGINAL LID

In CATIA V5, apply the pressure at 200°C at super heater state of steam for thermal analysis. The various parameters used for finite element analysis for modified inner lid of pressure cooker are,

Material=Aluminium;Young Modulus= e+010N_m2;
Poisson Ratio = 0.346;Density = 2710kg_m3;
Thermal Expansion = 2.36e-005_Kdeg; Yield Strength = 9.5e+007N_m2

Meshing & Von Mises Stresses for existing inner lid are as shown in figure 05 & 06 respectively.



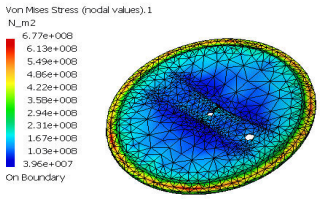
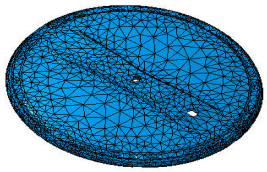


Fig. 05: Mesh for original lid **Fig. 06: Von Mises Stress for original lid**

Meshing & Von Mises Stresses for modified inner lid are as shown in figure 07 & figure 08 respectively



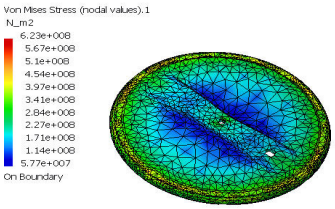
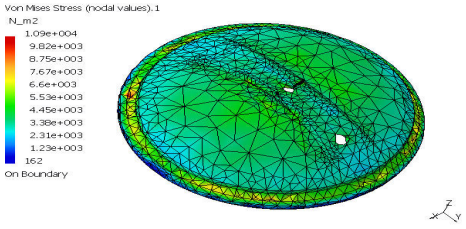


Fig.07 Mesh for modified lid **Fig. 08 Von Mises Stress for modified lid**

SIMPLE STRESS & THERMAL STRESS ANALYSIS

After applying the same forces at the same conditions of temperature to both the lids in CATIA V5, the thermal stresses developed in lids are as shown in fig.7 &fig. 8



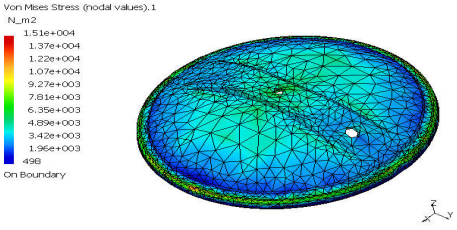


Fig.7 Original inner lid **Fig.8 Modified inner lid**

From these results, it clear that the stresses developed in the modified inner lid is negligibly higher than existing inner lid which is not dangerous. Also it is not developing at the circumference of the modified inner lid. Hence the modification in the inner lid is acceptable.
Also we can compare the existing & modified inner lid of pressure cooker as

Sr. No.	Descriptions	Original pressure cooker	modified pressure cooker
1	Exposed area	Less	More
2	Time of cooling	More	Less
3	Handling of inner pot	Obstructed	Easier
4	Stress developed	More	Less

From this it is clear that modification suggested in existing inner lid of pressure cooker for fulfillment of need

CONCLUSION

On the basis of the work done so for following conclusion are drawn.
1. Modifying the shape of inner lid of pressure cooker from elliptical to circular with straight edges, area is increased for heat dissipation from food to the atmosphere is by 14.54%.
2. The stress analysis for the original lid as well as of the modified shape of inner lid of pressure cooker renders the conclusion that the stress increases in the modified design. However the increase in stress is slight. Also the thermal stress analysis in the modified shape of pressure cooker is less.
3. As the area of heat dissipation is increased in modified pressure cooker, so cooling of the food become faster. Hence waiting time for removing the food pots is reduced.
4. As the area is increased in modified pressure cooker hence the food pots can be easily removable without obstructing. Hence accident of burning is avoided.

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