Pressure Cooker with Modified Lid

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Abstract: - Without the pressure cooker, kitchen is like a human being without the sole. Now a days cooker in kitchen is not only the fashion but also the need of woman / man. So pressure cooker become the inevitable item in kitchen due to time & energy properties. From ancient time, many researchers had been made on cooking and advised to energy in support indirectly to save energy. In energy saving, electrical or solar, alternative sources, were also play an important role. Saving energy may be direct or indirect. Some researchers gave various ways of direct and indirect energy saving by modified design of pressure cooker. This change may be in the form of shape, size, material etc. of the lid. The existing shape of inner lid of pressure cooker is elliptical. The shape is for locking & unlocking of the lid, ease of handling. Even to it has certain disadvantages. To overcome these, different shapes of inner lid were arising. The variations in lid started from circular to ellipse via other geometrical shapes. Irrespective of advantages, this lid shape also has some demerits. These demerits has been overcome by modified lid. This lid is the hybrid lid having advantages of both circular and modified lids. The modified lid serve all purposes intended by existing lid and give better results for locking; saving in cooling time of food, increase in heat transfer area and reduction in turning angle.

Key-Words: - Pressure cooker (PC), Elliptical Shape, Energy, Modified Lid, Thermal stresses, Heat Transfer Area.

1 Introduction

Any vessel which operates under pressure or above atmospheric pressure can be called as pressure vessel [23]. Such vessels are designed according to the pressure vessel codes. When the pressure is maintained inside the vessel, it is subjected to internal pressure. This pressure is higher than atmosphere. Under the action of this pressure, the stresses [14] induced in the vessel are

- Hoop stresses or circumferential stresses
- Longitudinal stresses
- Radial stresses

While designing, the stress variation at low pressure is neglected, but it is considered at high operating pressure [41]. The stress variations in all above stresses are appreciable. Out of these, tangential stress play vital role design of PC. So it should be considered for the design of pressure cooker. Basically there are two types of cooker i.e. inner & outer lid. Both cookers are working on the same principle. Here existing and modified lid shape for pressure cooker [28] is restricted to inner lid only.

2 Problem Formulation

The existing inner lid of the pressure cooker is having the elliptical shape. This shape is for inserting the lid into pressure vessel. Locking is done by inserting minor axis of lid in the major axis opening of pressure vessel near about 90^{o} & turns the handles till matching both axes & press the clip to lock. By social survey of women at different places, they pointed about special skill for locking & unlocking during opening & closing of cooker, obstruction for putting & removing pot due less opening area, taking out pots from pressure vessel in hurray causes spilling of food in or out of pressure cooker & sometimes cause burning to them. These problems are the main theme of this thesis. The root causes of these problems are hidden in lid shape. So thesis focuses on modification of shape of inner lid from elliptical shape to circular shape having straight edges at periphery as shown in figure 01.

Figure 01- Shape change of lid

2.1 Working of PC

The household pressure cooker works on steam pressure. The steam is generated by heating the

water inside the PC up to boiling point i.e. 100° C. Boiling of water is the starting point of steam generation. When temperature reaches to 120° C, superheated steam is generated & simmering action of food starts cooking in this temperature range. Slowly pressure is increasing with temperature and whirling of steam starts inside. This steam exerts pressure internally on top surface of PC. When this pressure is in between 170 KPa to 200 KPa, the lid is subjected to very high force. This force is balanced by dome shape with whirling action of steam and excess pressure is released through vent pipe. The release of excess pressure is alarmed by whistle in PC. To avoid choking of vent pipe, plug valve is provided in lid at proper location.

2.2 Inner Lid Revolution

Chavich and Toranto had started to invent easiest way of locking [7] and tried to avoid complicated locking system. The aim was to insert inner lid in pressure vessel pot easily. From leak-proof point of view, locking of lid to pot [38] and ease of operation, both had changed lid shape from circular to rectangular followed by other polynomial shapes as square, triangle, pentagon, hexagon and elliptical as in figure 02.

Figure 02- Inner Lid Revolution

Charles Darvin supported design of pressure cooker by his investigations not only for low level altitude location but also for hilly regions. In literature reviewing, the journey of innovation in inner lid [5] started from circular to elliptical inner lid. The discussion was made over the various shape and found certain merits and demerits. By overcoming the demerits, generation of new inner shape would be created.

The first lid for pressure cooker was circular lid. In this maximum stress concentrations were at periphery and hence special locking attachment [7] was required. To overcome the difficulties of circular lid, the alterative rectangular shape lid was introduced. But again lid had not only maximum stress concentration at the corners [24], but also cause accident due to sharp corners. The same lid also had difficulty in production of dome shape [10] which need in whirling of steam within PC and also required special locking attachment [11]. Hence this lid was not up to the mark of customer. The new alternative was the triangular lid. It had same disadvantages as like rectangular lid along with less heat transfer area. So it was again weak alternative. Next alternatives were pentagonal and hexagonal lids [16]. The disadvantages of these were not only maximum stress concentration at sharp corners but also manufacturing [23] of dome and requirement of special locking. These lids were aesthetically good but sharp corners causes accident and steam leakage problem through blended corners. So they didn't stand as alternative against previous lids.

Hawkins invented elliptical shape by overcoming remedies maintained by Chavich [17]. He started his own company production by name "Hawkins Pressure Cooker". After very long research survey, Hawkins gave elliptical shape to inner lid of pressure cooker.

Now in the market various inner lid pressure cookers [18] are available. Those brands are Hawkins, Prestige and others having elliptical inner lid with variations only in shape of pressure vessel. The working procedures for each of them are same. Hence change in lid has not disturb other design of PC.

The comparative details among the various inner lid shapes by considering merits and demerits have been elaborated in Table 01. The table enhance to exhaustive literature survey to clarify all the queries in mind.

Table 01- Comparisons between Inner Lids

Description	Inner Lid Shapes of Pressure Cooker						
	○	□	◇	△	⬠	⬡	⬭
Inserting	Easy	Difficult	Difficult	Difficult	Difficult	Difficult	Easy
Locking Arrangement	Externally	Externally Require Special locking Skill	Externally Require Special locking Skill	Externally Require Special locking Skill	Externally Require Special locking Skill	Externally Require Special locking Skill	Externally Require Special locking Skill
Locking Angle	0°	30° - 60°	60°	60° - 75°	60° - 75°	60° - 75°	90°
Ring Design	Easy	Difficult	Difficult	Difficult	Difficult	Difficult	Difficult
Material Availability	Easily	Easily	Easily	Easily	Easily	Easily	Easily
Production	Easy	Easy	Easy	Easy	Difficult	Difficult	Difficult
Dome Design	Easy	Difficult	Difficult	Difficult	Difficult	Difficult	Easy
Stress Concentration	Maxi. At Periphery	Maxi. At Corners	Maxi. At Corners	Maxi. At Corners	Maxi. At Corners	Maxi. At Corners	Maxi. At Periphery
Safety	Good	Bad	Bad	Bad	Bad	Bad	Good
Heat Transfer Area	More	Less	Very Less	Very Less	Less	Less	Medium
Cooling Time	Less	More	More	More	More	More	More
Aesthetic Look	Pleasant	Horrible	Good	Horrible	Horrible	Pleasant	Pleasant
Handling	Easy	Difficult	Easy	Difficult	Difficult	Difficult	Easy
Efficiency	Average	Less	Less	Less	Less	Less	More

3 Modified Lid

For existing elliptical lid special attention and skill is required for locking and unlocking properly. If locking is not proper, accidental situation may arise, which is dangerous to working woman / man. That's why, as a first preference to safety and security, benefits of maximum heat and mass transfer [29] during cooking operation, modified lid is invented. Modified lid is having circular shape with straight edges at its periphery [30]. The straight edges of lid are for locking & unlocking of lid with pot. The outlines of existing and modified lids are collectively represented by figure 03. The shaded portion shows surplus area provided by modified lid which is beneficial for fastest heat transfer from pressure vessel opening to the atmosphere & easier handling of pots.

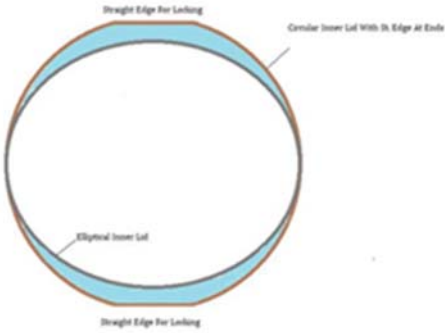


Figure 03- Outline of Both Lids

4 Experimentation

By the change in lid shape from elliptical to modified, we obtain following advantages.

1. Increase in Heat Transfer area.
2. Reduction in cooling time for food.
3. Ease of handling of inner pots.
4. Reduction in peripheral stresses
5. Good aesthetic look.

For support to above advantages, both lids are analyzed by following different criteria as

4.1 Area Analysis

Pressure cooker of 3 liters capacity is considered for mathematical modeling, software modeling by CATIA and experimentation.

Increase In Area

For elliptical shape of inner lid of pressure cooker,

Major Axis = 156 mm, Minor Axis = 136 mm

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

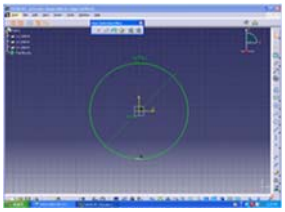
Where a = major axis /2 =156/2 =78 mm

b = minor axis /2 =136/2=68 mm

$A_{elliptical} = \pi \times 78 \times 68$

$= 16650 \text{ mm}^2$

The modified shape [39] of inner lid of pressure is circular inner lid with straight edges at periphery having dimensions as



Diameter of circular portion = 156 mm

Length of straight edge = 10 mm

Area of modified lid $= A_1 - A_2$

Where A_1= Area of Circular Shape

A_2= 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 st. 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 st. at Centre

$= 20^\circ$

$A_2 = 2 \times [78/2(\pi \times 20^\circ/180^\circ - \sin 20^\circ)]$

$= 42.58 \text{ mm}^2$

Area of circular inner lid with straight edges =19113.44 - 42.58

$A_{modified} = 19070.86 \text{ mm}^2 \approx 19071 \text{ mm}^2$

Increase in area exposed for steam to atmosphere

$A_{advantage} = A_{modified} - A_{elliptical}$

$= 19071 - 16650$

$= 2421 \text{ mm}^2$

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

= 14.54 %

4.2 Increase In Heat Transfer Area

Amount of heat dissipated [38] per unit length is given by

$Q = h A \Delta T$

Where

h=convective heat transfer coeff.

A=Heat Transfer Area

ΔT= Temperature difference

As h, ΔT is constant for both lids, so only A i. e. area is variable. Hence Amount of heat [42] dissipated per unit length i.e. Q is directly proportional to Area.

4.3 Easier handling of Inner Lid

While keeping or removing different pots in the pressure vessel through elliptical opening, these are obstacting with inner edges of the pressure vessel. But the same pots can be easily put or remove in modified pressure vessel due to more opening area. It can be supported by,

Area of elliptical lid $A_{elliptical} = 16650\ mm^2$

Area of circular lid with straight edges

$A_{circular} = 19783\ mm^2$

Increase in area for handling of pots

$A_{advantage} = A_{circular} - A_{elliptical}$

$= 19071 - 16650$

$= 2421\ mm^2$

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

= 14.54 %

As 14.54 % more area is available for easier handling of pots, so that the pot will not stickled to pressure vessel & avoid spilling of food in & outside of pressure cooker.

4.4 Thermal Stress Analysis

Modeling of various parts of both pressure cooker is done in CATIA-V5 and applied pressure for calculation of thermal stresses at periphery of both lids. The same results are compared by experimental results obtained at Krish-Tech laboratory, Pune, India.

4.4.1 Thermal Stresses by CATIA

For thermal stress analysis in CATIA-V5, different locator points for elliptical and modified lids are as shown in figure 04.

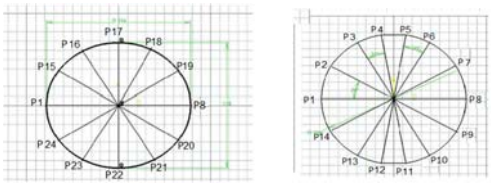


Figure 04- Locator Points for both Lids

Elliptical Lid

At 120° C temperature & corresponding 170 KPa pressure, thermal stresses [40] developed at periphery of elliptical lid and pot in CATIA are as shown in figure 05 and tabulated as in Table 02. Here P1, P8, P15, P16, P17, P18, P19, P20, P21, P22, P23 & P24- Stress Locator Points.

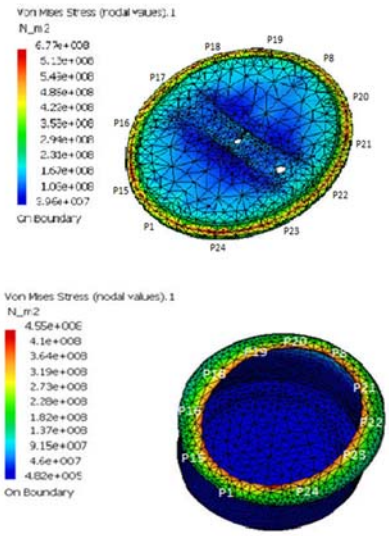


Figure 05 - Elliptical Lid & Pressure Vessel

Table 02 Thermal Stresses for Elliptical Lid

Locator Point	Von Mises Stress (N_m2)
P1, P8	4.86e+008
P15, P19, P20, P24	5.43e+008
P16, P18, P21, P23	5.68e+008
P17, P22	4.22e+008

Modified Lid

By the application of same pressure and temperature [49] under same conditions, thermal stresses developed in modified lid and pressure vessel is as shown in figure 06 and tabulated as in Table 03. Here P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13 & P14- Stress Locator Points.

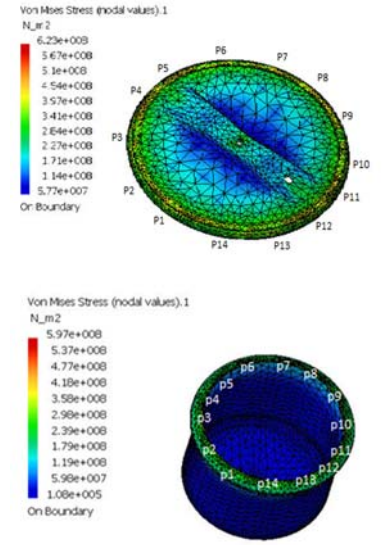


Figure 06 - Modified Lid & Pressure Vessel

Table 03- Thermal Stresses Modified Lid	
Locator Point	Von Mises Stress (N_m2)
P1, P8	3.57e+008
P2, P7, P9, P14	3.91e+008
P3, P6, P10, P13	4.54e+008
P4, P5, P11, P12	5.15e0+008

4.4.2 Thermal Stresses by Experimentation Elliptical Lid

With same conditions considered in CATIA analysis, the experimentation is done for both lids. Considering the manual, experimental & material errors, the thermal stresses for elliptical & modified lids are calculated as in Table 04 & 05 respectively.

Table 04-Thermal Stresses for Elliptical Lid

Experimental Results of Elliptical Lid

Strain Gauge Points for Elliptical Lid = P1, P15, P16, P17, P18, P19, P8, P20, P21, P22, P23, P24

Pressure selected here is w.r.t temperature below and above 100° C

Pressure w.r.t. Temp.	Strain (P× 1.00E-04)											
	P1	P15	P16	P17	P18	P19	P8	P20	P21	P22	P23	P24
0.5 bar	43	70	70	33	79	71	47	84	80	33	78	78
1 bar	70	104	80	59	90	105	79	125	94	59	119	119
1.2 bar	74	126	100	71	109	137	83	142	115	71	138	138
1.5 bar	79	135	120	84	119	139	89	158	135	84	152	152

Youngs' Modulus for **Al** =E = 7.00E+10 N_m2

Pressure w.r.t. Temp.	Stress (N_m2)											
	P1	P15	P16	P17	P18	P19	P8	P20	P21	P22	P23	P24
0.5 bar	3.01E+08	4.90E+08	4.90E+08	2.31E+08	5.53E+08	4.97E+08	3.29E+08	5.88E+08	5.60E+08	2.31E+08	5.46E+08	5.46E+08
1 bar	4.90E+08	7.28E+08	5.60E+08	4.13E+08	6.30E+08	7.35E+08	5.53E+08	8.75E+08	6.58E+08	4.13E+08	8.33E+08	8.33E+08
1.2 bar	5.18E+08	8.82E+08	7.00E+08	4.97E+08	7.63E+08	9.59E+08	5.81E+08	9.94E+08	8.05E+08	4.97E+08	9.66E+08	9.66E+08
1.5 bar	5.53E+08	9.45E+08	8.40E+08	5.88E+08	8.33E+08	9.73E+08	6.23E+08	1.11E+09	9.45E+08	5.88E+08	1.06E+09	1.06E+09

Table 05-Thermal Stresses for Modified Lid

Experimental Results of Modified Lid

Strain Gauge Points for Modified Lid = P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14

Pressure selected here is w.r.t temperature below and above 100° C

Pressure w.r.t. Temp.	Strain (P× 1.00E-04)													
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0.5 bar	43	40	42	44	47	63	40	47	36	59	52	55	50	37
1 bar	70	65	69	83	84	66	68	79	60	80	92	88	76	62
1.2 bar	74	94	77	102	100	96	98	83	74	99	118	108	82	74
1.5 bar	79	103	90	112	112	103	100	89	85	111	126	120	94	88

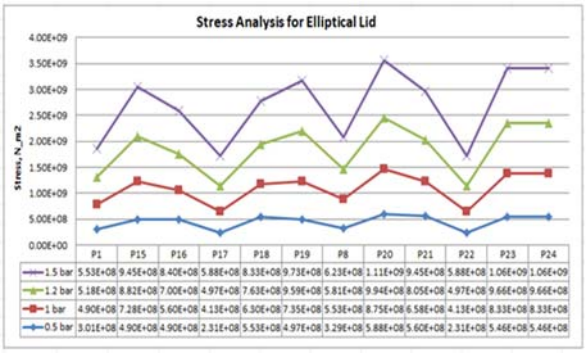
Youngs' Modulus for **Al** =E = 7.00E+10 N_m2

Pressure w.r.t. Temp.	Stress (N_m2)													
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0.5 bar	3.01E+08	2.80E+08	2.94E+08	3.08E+08	3.29E+08	4.41E+08	2.80E+08	3.29E+08	2.52E+08	4.13E+08	3.64E+08	3.85E+08	3.50E+08	2.59E+08
1 bar	4.90E+08	4.55E+08	4.83E+08	5.81E+08	5.88E+08	4.62E+08	4.76E+08	5.53E+08	5.18E+08	5.60E+08	6.44E+08	6.16E+08	5.32E+08	4.34E+08
1.2 bar	5.18E+08	6.58E+08	5.39E+08	7.14E+08	7.00E+08	6.72E+08	6.86E+08	5.81E+08	5.18E+08	6.93E+08	8.26E+08	7.56E+08	5.74E+08	5.18E+08
1.5 bar	5.53E+08	7.21E+08	6.30E+08	7.84E+08	7.84E+08	7.21E+08	7.00E+08	6.23E+08	5.95E+08	7.77E+08	8.82E+08	8.40E+08	6.58E+08	6.16E+08

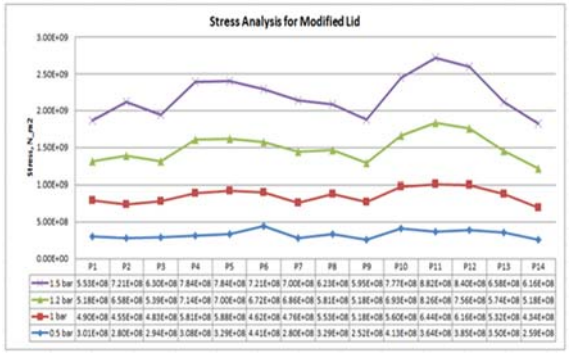
5 Result

The result analysis for thermal stresses are done through ANNOVA in Microsoft Excel. The graphical representation for elliptical & modified lids are as shown in Graph 01 & 02 respectively.

Graph 01-Th. Stresses v/s Pressure (at Locators)



Graph 02 – Th. Stresses v/s Pressure (at Locators)



The peripheral stresses which are important in pressure cooker are compared as shown in Table 06 and Graph 0 respectively.

Table 06 -Stress Analysis for lid

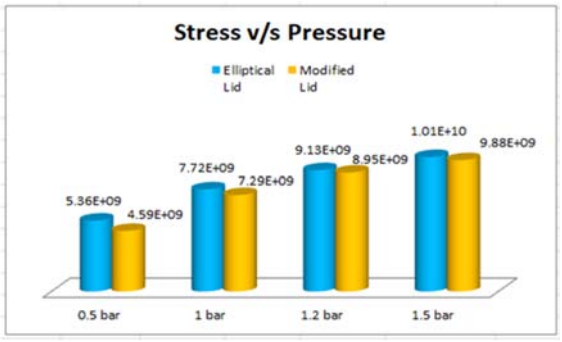
Stress Analysis Between Elliptical and Modified lid

Pressure w.r.t. Temp.	Strain at Periphery (1.00E-04)			
	0.5 bar	1 bar	1.2 bar	1.5 bar
Elliptical Lid	766	1103	1304	1446
Modified Lid	655	1042	1279	1412

Youngs' Modulus for **Al** =E = 7.00E+10 N_m2

Pressure w.r.t. Temp.	Stress (N_m2)			
	0.5 bar	1 bar	1.2 bar	1.5 bar
Elliptical Lid	5.36E+09	7.72E+09	9.13E+09	1.01E+10
Modified Lid	4.59E+09	7.29E+09	8.95E+09	9.88E+09

Graph 03- Th. Stresses v/s Pressure Lids



Graph indicates that thermal stresses at peripheral point of modified lid are less as compared with elliptical lid. Hence modified lid stands as best alternative to elliptical lid.

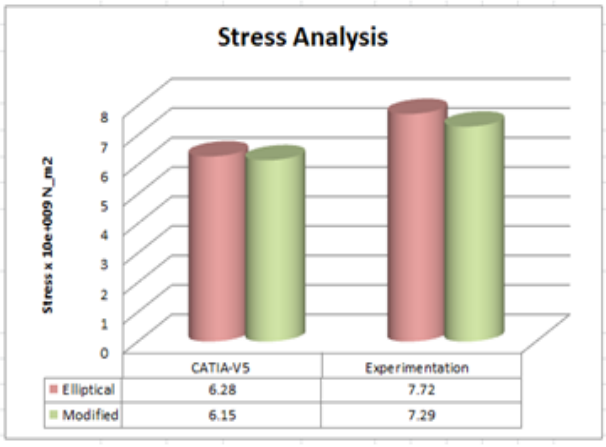
5.1 Software & Experimental Analysis:

Comparative studies between both lids by CATIA-V5 & Experimentations are tabulated in Table 07 and Graph 04.

Table 07- Stress Comparison

Sr. No	Lid	CATIA-V5	Experimentation
1	Elliptical	6.28×10^9 N/m^2	7.72×10^9 N/m^2
2	Modified	6.15×10^9 N/m^2	7.29×10^9 N/m^2
Remark		*Stress < elliptical lid*	*Stress < elliptical lid*

Graph 04- Total Th. Stresses v/s Pressure



6 Conclusion

From above results and analysis by different parameters, advantages obtained by modified lid over elliptical lid in tabulated form are as in Table 08.

Table 08-Tabular Analysis

Sr. No	Parameters	Elliptical lid	Modified lid	Remarks
1	Opening Area	16650 mm^2	19071 mm^2	2421 mm^2 available by modified pressure vessel of PC
2	Heat Transfer Area	16650 mm^2	19071 mm^2	14.54% More Heat Transfer Area by modified lid of PC
3	Locking Angle	90°	20°	Less efforts for locking and unlocking in modified of PC
4	Cooling Time for Food	93 seconds	27 seconds	Save 66 seconds time by modified lid of PC
5	Thermal Stresses by CATIA-V5	6.28×10^9 N/m^2	6.15×10^9 N/m^2	0.13×10^9 N/m^2 less stresses at periphery generated in modified lid of PC
6	Thermal Stresses by Experimentation	7.72×10^9 N/m^2	7.29×10^9 N/m^2	0.43×10^9 N/m^2 less stresses at periphery generated in modified lid of PC
7	Safety	Lack of concentration, more chance of burning	Lack of concentration, less chance of burning	More safety in modified lid of PC
8	Food wastage	More spilling out of food due to striking pots with vessel	Less spilling out of food due to striking pots with vessel	Save food by modified lid of PC
9	Appearance	Pleasant	More Pleasant	Aesthetically better for modified lid of PC

From above table in all respect, **modified lid is replacing elliptical lid**, as best alternative. This will be bring strong revolution in the word of inner lid pressure cooker. As this innovation wiil create revolution in pressure cooker, hence **Indian Patent** is filed with **Docket No 17552 Date/Time 2018/04/14 11:59:56.**

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