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Modified Inner Lid of Pressure Cooker

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Abstract: *Kitchen without pressure cooker is like a human being without sole. Researchers was about to save energy in support of 'Save Energy' motto of various nations. Some researchers gave different methods of direct energy saving. This change may be in the form of shape, size, material etc. Existing shape of inner lid is an elliptical. This shape is for comfort of locking & unlocking the lid, ease of handling to working woman / man. But in actual working, there is lot of difficulties. Need of skill for locking, less heat transfer area, accidental burning etc. are the drawbacks of existing lid. To overcome these demerits, different alternatives for the lid shape & others were arising. Considering design and manufacturing restrictions, designers concentrated on lid shape only. By taking advantages of circular & elliptical shape, a modified lid i.e. circular shape having straight edges at periphery is invented.*

Keywords-*Elliptical shape, Modified lid, Pressure cooker, Solar energy, Thermal stresses*

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I. INTRODUCTION

The existing inner lid of PC is having of elliptical shape. For locking, first insert lid is inserted by minor axis of lid in major axis pressure vessel by making in between angle near about 90 ^{o} & then turn the handles up to matching of major axis of lid with major axis of pressure vessel. Press the clip on handle to lock the lid with vessel. For unlocking, follow the reverse procedure. This operation needs special skill. Slight misalignment creates major accident in kitchen. With help of social survey, women from different places also pointed out the same difficulty. They need special skill for inserting & removing lid. So, elliptical lid is difficult for inserting and removing. After cooking the food in PC, everyone is in hurry for taking out the pots. But due to the steam, burning may happen. It is better to wait for few moments so that food gets cooled. At this situation, entrapped steam along with food is escaped from elliptical or modified opening of pressure vessels. The steam is now directly exposed to the atmosphere. This process continues till equilibrium state between food and atmosphere. Also kitchen woman / man try to take out pots from pressure vessel in hurray, which cause spilling of food in or out of pressure cooker & sometimes cause burning too. So this thesis concentrates on inserting, locking & waiting time after cooking of food in pressure cooker. The root cause of these problems is lid shape.

II. PRESSURE COOKER

1.1 Stresses

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. The inside pressure is higher than atmosphere. Under the action of internal 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 at high operating pressure [41], variations in all above stresses are appreciable. Out of these, tangential stress variation is more & hence it should be considered for the design of pressure cooker. There are two types of cooker i.e. inner & outer lid pressure cooker. Both cookers are working on the same principle. In this paper, existing and modified lid shape for pressure cooker [28] is restricted to inner lid type.

1.2 Working of PC

Pressure cooking is a method of cooking in a sealed vessel that does not permit air or liquid to escape below a preset pressure value [1]. After reaching 100 ^{o}C temperatures i.e. the boiling point of water, pressure is built up inside the cooker. The food to be cooked is placed in the pressure cooker with a small amount of water.

The vessel is then sealed & placed on heat source. e.g. a stove. As temperature inside PC rises, pressure reaches to design gauge pressure. Mostly working pressure for cookers have 15 psi (107 KPa) over the existing atmospheric pressure i.e. the standard set by the United States department of Agriculture in 1917. For air tight seal of lid with vessel, gasket and lid lock arrangement with flanges are used. This provides the trapping of pressurized steam inside vessel and also not allowing the steam to escape before preset pressure as per standard. This prevents accidental removal during cooking of food.

1.3 Modification in Inner Lid

The existing inner lid of the pressure cooker is of elliptical shape. In this, lid is locked in the pressure vessel pot by inserting it through its minor axis side with major axis side of pot & turning them till perfect matching of their major axes for perfect locking. A special skill is necessary for locking and unlocking the lid 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, researchers invented modified lid i.e. circular shape with straight edges at its periphery for pressure cooker [30] as shown in "Fig.01". The straight edges of lid are for locking & unlocking of lid with pot. The shaded portion shows surplus area by modified lid for heat transfer for the benefit of fastest heat transfer to atmosphere.

1.4 Inner Lid Revolution

Chavich and Toranto had started to invent easiest way of locking [7] and try to avoid complicated locking system. The first step to that 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 square, triangle, pentagon, hexagon and elliptical as shown in "Fig. 02".

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 details about these are discussed subsequently. 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 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] for whirling of steam within PC. For which, special locking attachment [11] was to be provided. Hence this lid was not up to the mark of customer. Next alternative was the triangular lid. It had same disadvantages as like rectangular lid plus 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 difficulties [23] of dome and requirement of special locking arrangement. These lids were aesthetically good but sharp corners causes accident and leakage problem of steam blended corners. So they didn't stand as alternative against previous lids.Hawkins invented elliptical new 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 to pressure cooker. Now in the market various inner lid pressure cookers [18] are available. The different brands are Hawkins, Prestige and other local brands. But all are having elliptical inner lid but variations only in bottom pressure vessel. The working procedures for each of them are same. Hence change in lid will not disturb other pattern of inner lid PC. The comparative details among the various inner lid shapes by considering merits and demerits have been elaborated in "Table". It enhances to exhaustive literature survey to clarify all the queries in mind. By exhaustive literature survey, it was cleared that all modern pressure cookers are coming from places France, Switzerland, Spain and Italy [27] and of elliptical lid type. But now days Indian Pressure Cooker also give the best alternative due to "Make In India" concept. It is clear that maximum innovation are made over inner lid shapes to enhance heat transfer, less cooking time and ease of handling for everyone.Though existing elliptical lid serves all purposes of cooking, but there are certain demerits about working and technical aspects. To fulfill all requirements of working woman / man without much more modification, why should we not thinking about hybrid lid having combinations of merits of circular and elliptical lid as shown in "Fig.".If we change the lids shape from elliptical to circular shape having straight edges at periphery, we may result following advantages.

a) Increase in Heat Transfer area.
b) Reduction in waiting time for food cooling.
c) Ease of handling of inner pots.
d) Good aesthetic look.

1.5 Analysis

For our demo purposes, here a pressure cooker of 2.5 liters is considered for analysis of various parameters [2] for mathematical modeling, software modeling by CATIA and experimentation. The parameters are as

a) Increase In Area

For elliptical shape of inner lid of pressure "Fig.".

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

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

$= 16650\ mm^2$

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

Diameter of circular portion = 156 mm

Length of straight edge = 10 mm

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

Where A_1= Area of Circular Shape

A_2= Area of two chord at straight edges

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

Area of two chord at straight edges = $A_2 = 2\times [r_2/2(\pi\times \theta/180^\circ - \sin \theta)]$

Where r_2 = radius of circular part = 156/2=78 mm

θ = angle subtended by straight at Centre of lid

$= 20^\circ$

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

$A_2=42.58mm^2$

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

$A_{modified} = 19070.86\ mm2 \approx 19071\ mm^2$

Increase in area exposed for steam to atmosphere = $A_{advantage}$

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

$= 19071 - 16650$

$= 2421\ mm^2$

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

= 14.54 %

b) 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 coefficient of material

A=Area through with heat is passing

ΔT= Temperature difference

Here h, ΔT is constant for both lids and only A i. e. area is variable.Hence Amount of heat [42] dissipated per unit length i.e. Q is directly proportional to Area of inner lid of the pressure cooker.

c) Easier handling of Inner Lid

While keeping or removing the different pots in the pressure vessel through elliptical opening, it will be obstructed with the inner edges of the pressure vessel. But the same pots can be easily kept or removed with the circular opening with straight edges at periphery. This is because of more available area of pressure vessel. This can be proved as,

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 easy handling of pots, so that the pot will not stickled to pressure vessel. Hence pots are easily handled.

1.6 Modeling by CATIA

a) Thermal Stress Analysis of Elliptical Lid

After modeling of various parts of PC, the assemblies [49] of existing and modified lids are shown in "Fig."&"Fig." respectively.By applying temperature 120 ^{o} C and pressure 170KPa to the elliptical lid, thermal stresses [40] developed in lid and pot by CATIA are as shown in "Fig." & "Fig." respectively.

b)Thermal Stress Analysis of Modified Shape

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 "Fig." & "Fig." respectively.

1.7 Experimentation

Experimentation is carried out for 3 liter capacity elliptical and modified inner lid pressure cookers under the same conditions of steam pressures and temperatures. Maximum stresses are developed at their periphery. The line and experimental set up diagrams is as in "Fig.".

1.7.1 Strain Gauge Marking

Strain gauges were attached at P1, P8, P15, P16, P17, P18, P19, P20, P21, P22, P23 and P24 locator points for elliptical lid & P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13 and P14 for modified lid as shown in "Fig.".

1.7.2 Experimentation

The experiments were carried out by

i) Experimental set-up as above.
ii) Applying pressure through compressor according to boiling point temperature.
iii) Measuring strain gauge readings at locator points for both lids at equilibrium conditions.
iv) Doing stress calculations with the help of Young's Modulus for aluminum.
v) Nomo graphs analyses by Microsoft excel Annova.
vi) Stress analysis by software and mathematical modeling.
vii) Compare total stresses at periphery for both lids.

1.7.3 Experimental Stress Analysis

Thermal stresses are calculated by considering Young's Modulus for Aluminum for both lids as E= 7 × 1010 N/m^2& actual readings obtained from experiments as follow.The thermal stresses at various locators against the applied pressure are represented graphical as in "Fig.". It indicates stresses at peripheral points for elliptical lid for pressures at below and above B.P.The thermal stresses at various locators against the applied pressure are represented graphical as in "Fig.". It indicates stresses at peripheral points for modified lid for pressures at below and above B.P.From above two experiments, it is clear that at 1 bar pressure for both the lids, thermal stresses induced in modified lid at various locator points are slightly less as compared to elliptical lid. So experimentally it is proven that modified lid is also safe at periphery.

III. Results And Analysis

The data obtained from software and experimentation is analyzed using Microsoft Excel Annova tool. This tool is useful for thermal stress analysis of both the lids to plot Nomo graphs. Here the locator points P_1 and P_8 are common for both lids, so same readings were carried out for modified lid. For various pressures, graph is plotted between pressure and induced stress as in "Fig.". It indicates that at 1 bar pressure, the stresses at periphery for modified lid are less comparing with elliptical lid. Graph indicates that thermal stresses at peripheral points of modified lid are less as compared to elliptical lid. Hence modified lid sustain all forces as like as elliptical lid from stress point of view.Similarly the stresses by CATIA and experimentation are tabulated in "Table"& compared in "Fig.".Graph clearly shows that by experimentally and software also, thermal stresses developed at periphery of modified lid are less compared to elliptical lid. Hence by this mode also modified lid stands as the best alternative to elliptical lid.From this analysis, it is very clear that surface and heat transfer area is increased by 14.54%. The locking and unlocking of lid with pressure vessel pot is reduced trough 50 ^{o} - 60 ^{o}. The modified lid is aesthetical best. The thermal stresses are reduced by 0.43 ×108 N/mm2.The final assembly of modified inner lid pressure cooker is as shown in "Fig.".

IV. Conclusions

Some of the conclusions of the present investigation are summarized as below:

- Mathematical model gives 14.54% more area for modified lid over elliptical lid. Same area is the more for opening of pressure vessels of modified pressure cooker.

- Because of more opening, handling of pots in and out of vessel is easier.
- After cooking, heat is escaping through pressure vessel opening. Hence 14.54 % more heat transfer area is provided by modified lid.
- Due to fast heat transfer through opening, cooling of food is faster in modified lid than existing. Hence waiting time for cooling food is reduced by 66 second.
- Angle of locking and unlocking of lid with vessel is reduced from 900 to 200. Also no special skill is required for this operation.
- Thermal stresses in modified lid are reduced by 0.13×109 N/m2 by software and 0.43×109 N/m 2 by experimentation as compared with elliptical lid. Hence modified lid stand good for stresses.
- Due to more opening of modified pressure vessel, handling of pots becomes easier. Hence no spilling and burning by steam / hot food.
- Because of circularity, modified shape is aesthetically good.
- In support of "Make in India" concept, patent is filed for this lid.

V. Recommendations And Future Scope

FIGURES AND TABLES

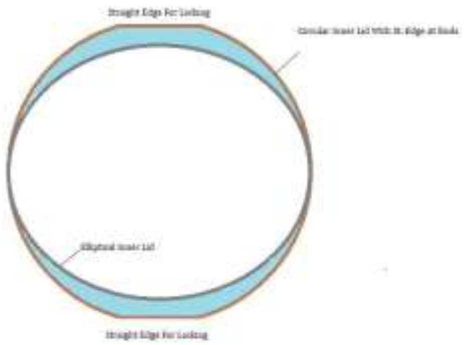


figure 01- lid area variation

figure 02- inner lid revolution

figure 03 - lid shape change

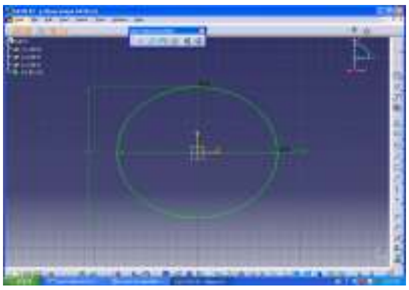


figure 04 - elliptical lid

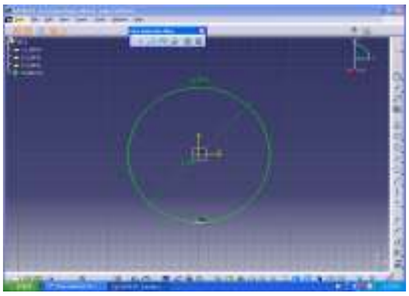


figure 05- modified lid

figure 06 - existing lid

figure 07 - modified lid

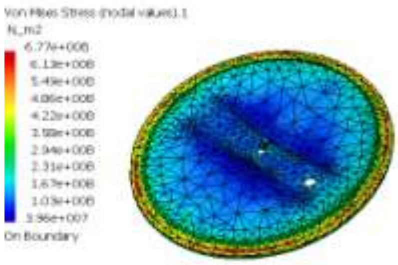


figure 08 - elliptical lid

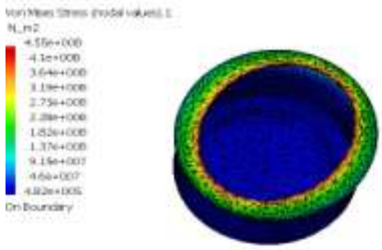


figure 09 - elliptical pv

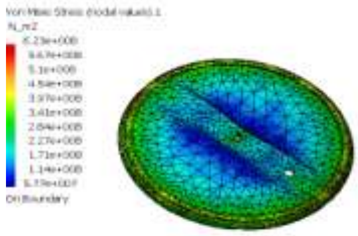


figure 10 - modified lid

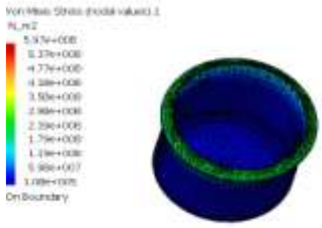


figure 11- modifiedpv

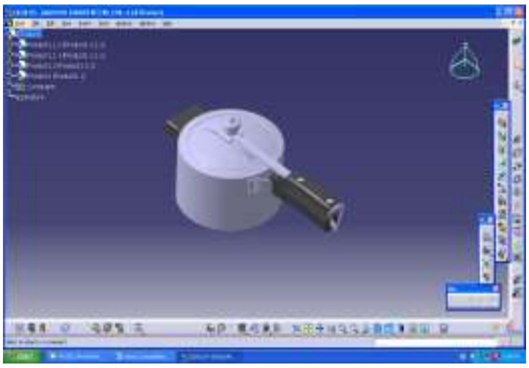


figure 12- modified pressure cooker

figure 13- line & experimental set up

figure 14- strain gauge marking

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

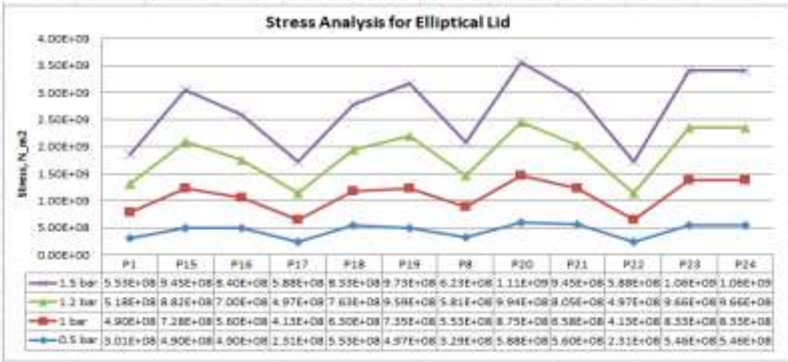


figure 15-thermal stresses v/s pressure for elliptical lid

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

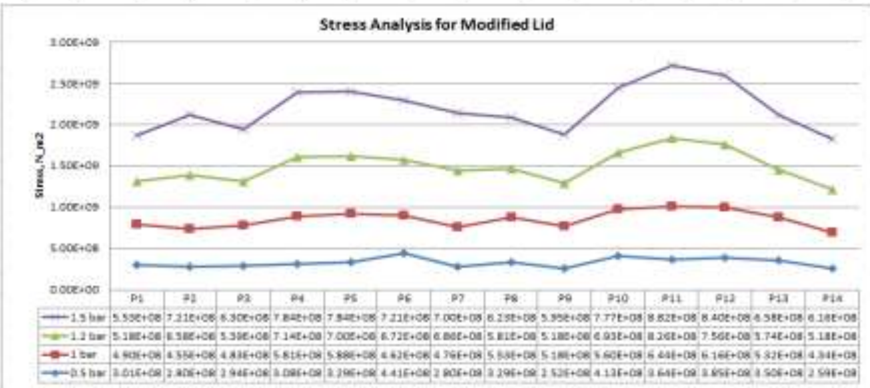
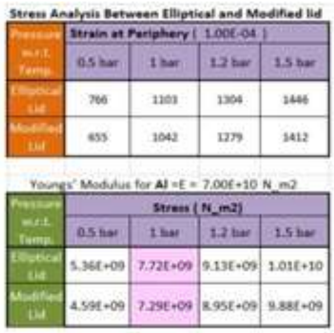


figure 16-thermal stresses v/s pressure for modified lid



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

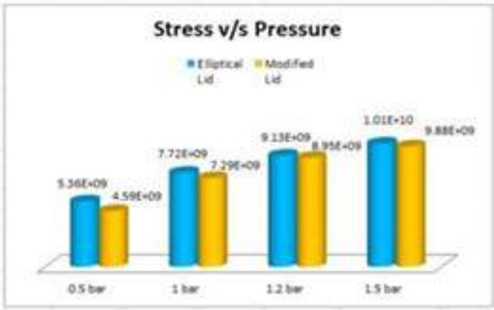


figure 17- stress v/s pressure

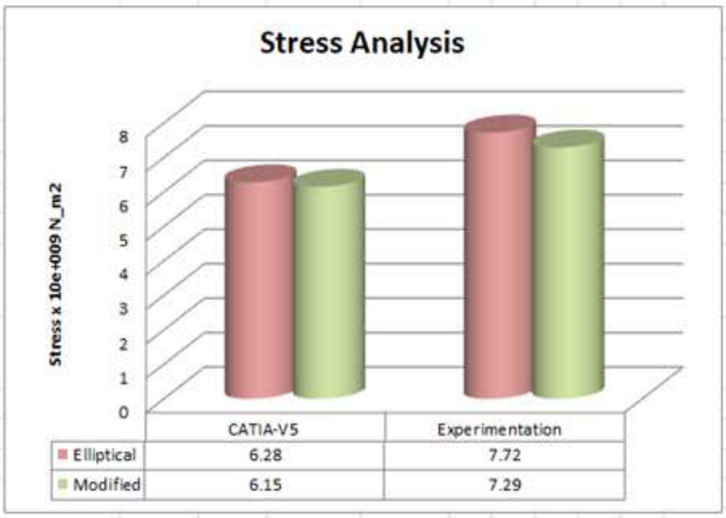
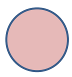
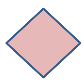
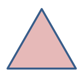
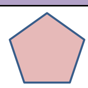
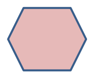
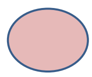


figure18- Total Stress

Table 1 Comparison 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	0^0	30^0- 60^0	60^0	60^0- 75^0	60^0- 75^0	60^0- 75^0	90^0
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

Table 01 Comparison of Lids

Sr. No	Details	Existing Inner Lid	Modified Inner Lid	Remark
1	*Surface Area*	16650 mm^2	19071 mm^2	Increased by **14.54%**
2	*Heat Transfer Area*	Less	More	Increased by **14.54%**
3	*Locking & Unlocking Angle*	70°-90°	20° - 30°	Reduced by **50 ° - 60 °**
4	*Aesthetic Look*	Good	Better	Best
5	*Thermal stress at rim*	6.67×10^8 N/mm^2	$6.23 \times 10^8 N/mm^2$	Reduced by **0.43 ×10^8**N/mm^2

Table 03- Stresses in Lid

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*

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