MODIFIED LID FOR PRESSURE COOKER

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Abstract: Now a day's having pressure cooker in kitchen is not only the fashion but also it becomes the important utensil of kitchen. Pressure cooker saves time & energy. From ancient time, researchers have been focusing on cooking. Their motto was to save thermal energy. The type of energy saving, may in electrical, solar etc. The save in energy may be direct or indirect. Some researchers gave various ways of direct energy saving & some were concentrated on indirect energy saving by change in design of pressure cooker. This change was in change in lid shape, size, material etc. The existing inner lid of pressure cooker is elliptical. The purpose of this shape is to lock & unlock the lid, ease of handling to working woman/man. The different alternatives for this shape were practiced. But due to manufacturing difficulties, designers concentrated on changes for lid shape of inner lid pressure cooker. The variations were started from circular to ellipse via various polygonal shapes. It is noted that elliptical shape has also some demerits. These demerits are overcome with hybrid lid having advantages of circular as well as elliptical lid. Formerly researchers followed different alternatives for the shape of lid; but this paper concentrate on modified lid i.e. circular shape having straight edges at periphery. This will be one of the best alternatives. This lid will also give better results in locking & increase in heat transfer area.

***IndexTerms* - Pressure cooker (PC), Elliptical Shape, Solar energy, Modified Lid.**

I. 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. 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.

II. 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°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.

III. MODIFICATION IN INNER LID

The existing inner lid of the pressure cooker is of elliptical shape. In this, lid is inserted in the pressure vessel by turning lid in the minor axis manner & returning it so that major axes are matched to lock the lid with vessel. A special attention is to be made for inserting and locking the lid properly. If proper locking is not happen, accidental situation may arise. This is dangerous to working woman / man. That's why, by giving preference to safety and security along with benefits of maximum heat and mass transfer [29] during cooking operation, researchers concentrated on change in shape of lid of pressure cooker [30].

3.1 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.1"**.

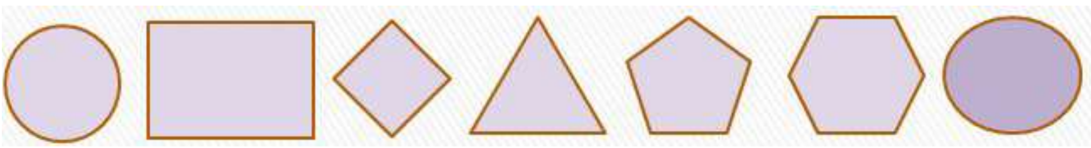


Figure 1: Inner Lid Revolution

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 details about these are discussed subsequently.

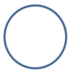
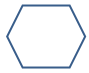
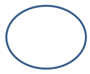
The first lid for pressure cooker was circular lid. In this maximum stress concentrations were at periphery and hence special locking attachment [7] was required. To overcome the difficulties of circular lid, the alterative rectangular lid was introduced. But again lid had not only maximum stress concentration 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 01. The chart 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	0^0	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

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. 2"**.

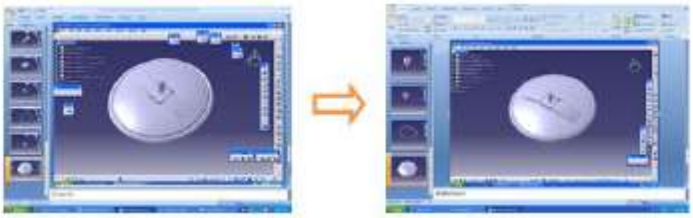


Figure 2: Change in Lid Shape

If we change the lids shape from elliptical to circular shape having straight edges at periphery, we may result following advantages.

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

3.2 Analysis

For our demo purposes, here a pressure cooker of 3 liters is considered for analysis of various parameters [2] for mathematical modeling, software modeling by CATIA and experimentation. The parameters are as

3.2.1 Increase in Area

From **"Figure 3"**, the analysis is carried out for 3 liters inner elliptical lid pressure cooker, to which dimensions are;

Major Axis = 156 mm
Minor Axis = 136 mm

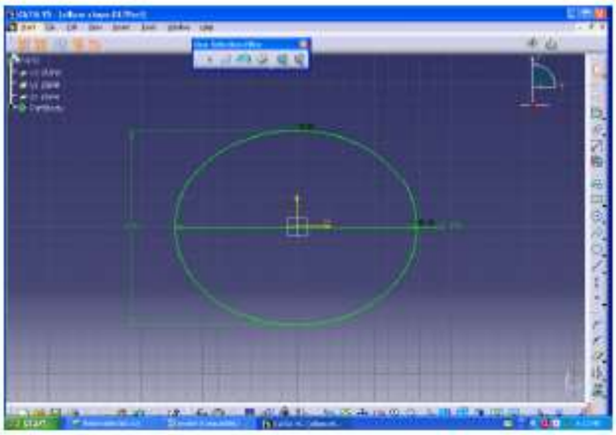


Figure 3: Elliptical Lid

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

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

$= 16650 \text{ mm}^2$

From **"Figure 4"**, the modified shape [39] of inner lid of pressure is circular inner lid with straight edges at its periphery with dimensions as

Diameter of circular portion = 156 mm

Length of straight edge = 10 mm

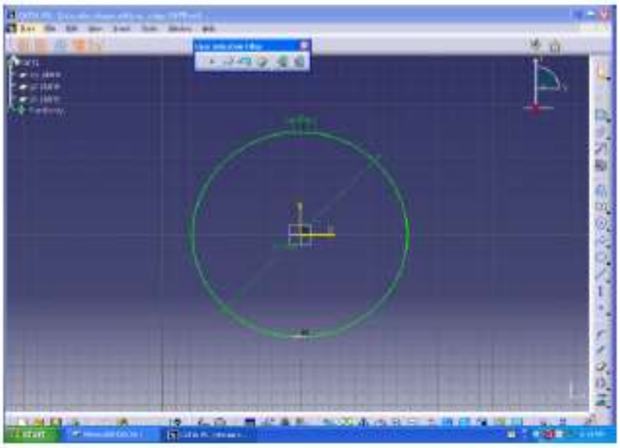


Figure 4: Modified Lid

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

$$\text{Area of Circular Shape} = A_1 = \frac{\pi(156/2)}{2} = 19112.44\ \text{mm}^2$$

$$\text{Area of two chord at straight edges} = A_2 = \frac{2 \times \left[\frac{r_2}{2}\left(\frac{\pi\times\theta}{180°}\right) - \sin\theta\right]}{2}$$

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

ɵ = angle subtended by straight at Centre of lid = 20◦

$$A_2 = \frac{2 \times \left[\frac{78}{2}\left(\frac{\pi\times 20°}{180°}\right) - \sin 20°\right]}{2} = 42.58\ \text{mm}^2$$

Area of circular inner lid with straight edges = A modified = 19113.44 - 42.58 = 19070.86 mm^2 ≈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** %

3.2.2 Increase in Heat Transfer Area

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

$$Q = hA\Delta T$$

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.

3.2.3 Ease to Handle

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.

IV. Analysis of Inner Lid

The analysis of inner lid for elliptical as well as modified shape is done by software & experimental.

4.1 CATIA Analysis

4.1.1 Thermal Stress Analysis

After modeling in CATIA-V5, the thermal stresses at temperature 120°C and pressure 170 KPa for elliptical lid and pot are shown in **"Fig.5"** & **"Fig.6"** respectively.

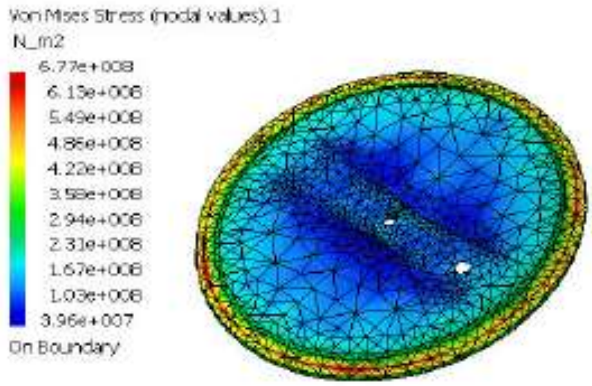


Figure 5: Elliptical Lid

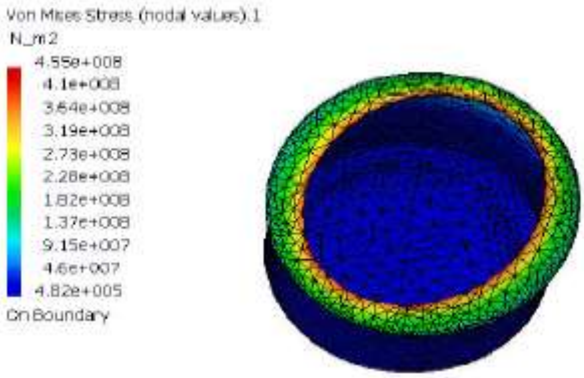


Figure 6 Elliptical Pot

After modeling in CATIA-V5, the thermal stresses at temperature 120°C and pressure 170 KPa for modified lid and pot are shown in **"Fig.7"** & **"Fig.8"** respectively.

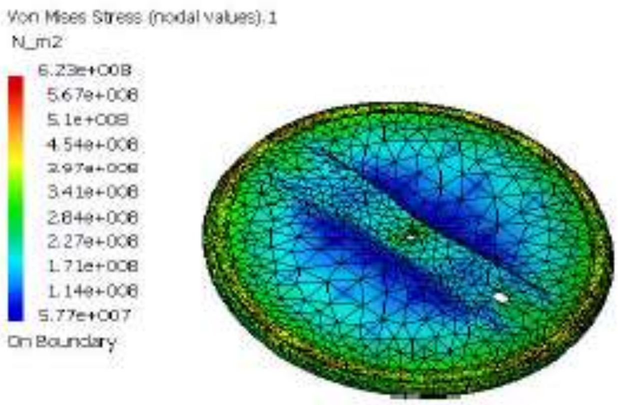


Figure 7: Modified Lid

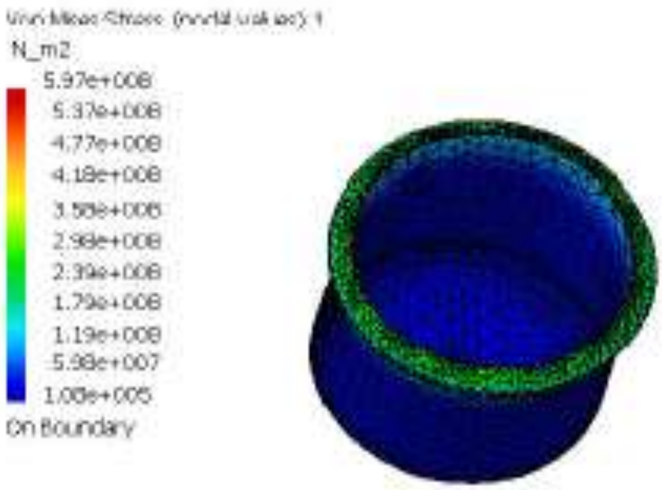


Figure 8: Modified Pot

4.2 Experimental Analysis

4.2.1 Experimental Stress Analysis

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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 2 & Table 3 respectively.

Table 02: 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 03: 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

V. RESULTS AND DISCUSSION

The result analysis for thermal stresses v/s pressure is done through ANNOVA in Microsoft Excel. The graphical representations for elliptical & modified lids are as in **"Fig.9"** & **"Fig.10"** respectively.

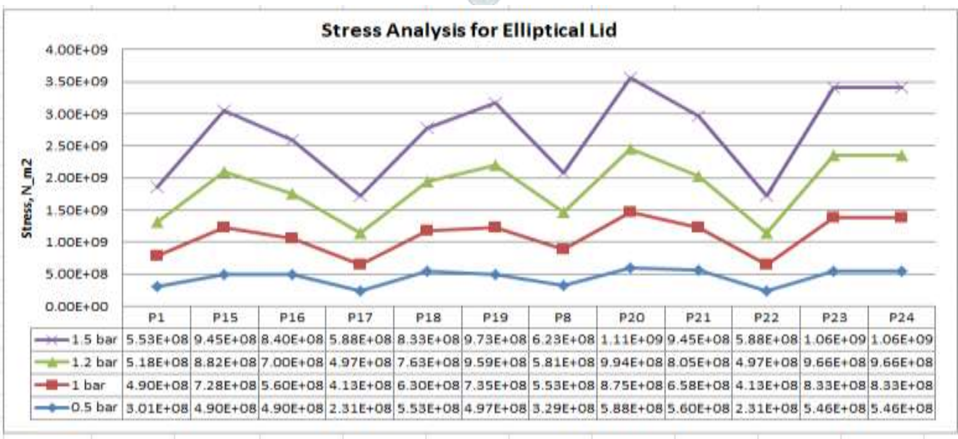

Figure 9: Thermal stress v/s Pressure for Elliptical Lid

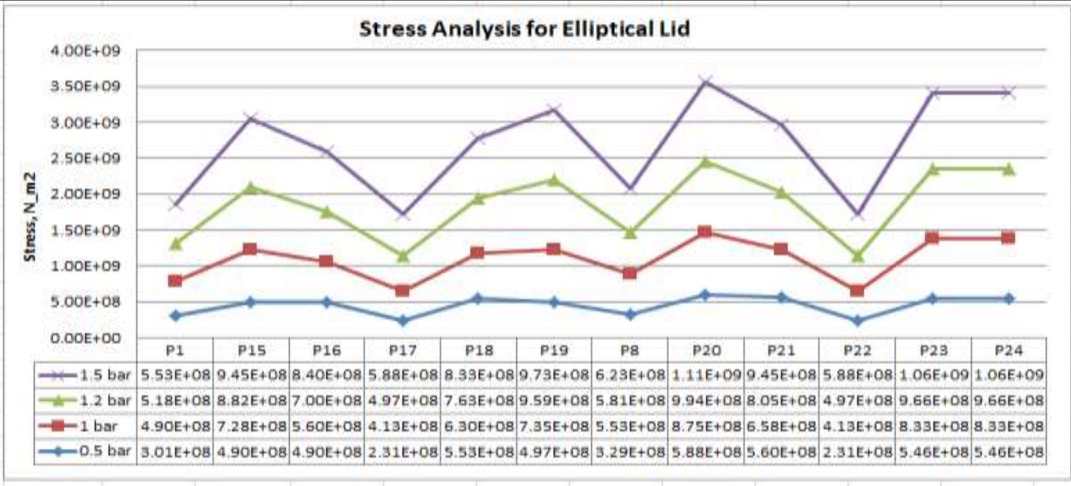

Figure 10: Thermal stress v/s Pressure for Modified Lid

Software & Experimental Analysis

Comparative study between both lids by CATIA-V5 & Experimentations is tabulated in Table 4 and **"Fig.11"**.

Table 04: Stress Analysis for elliptical & modified 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*

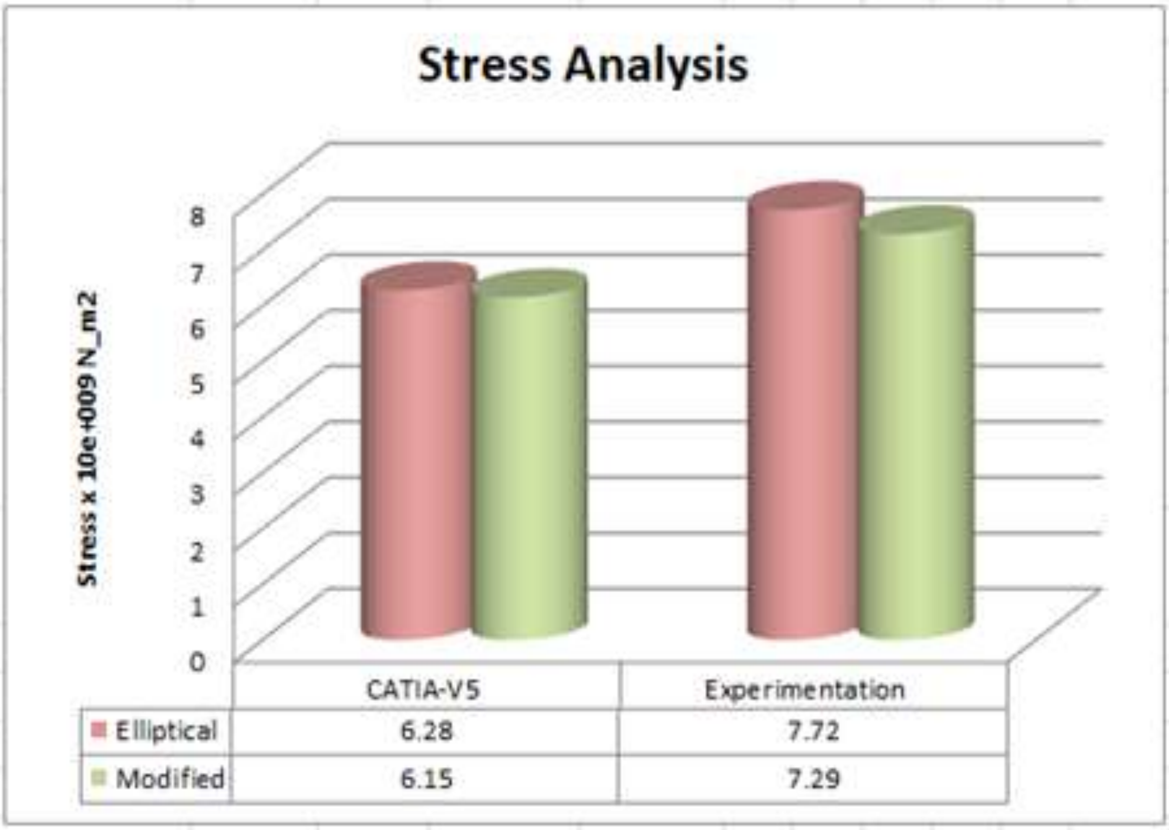

Figure 11: Thermal Stresses v/s Pressure (Modified & Elliptical).

Figure 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.

VI. CONCLUSIONS

From above results and analysis by different parameters, advantages obtained by modified lid over elliptical lid in tabulated form are as in Table 5.

Table 05: Comparison by Various modes

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 bringing strong revolution in the word of inner lid pressure cooker. As this innovation will create revolution in pressure cooker, hence Indian Patent was filed with Docket No 17552 Date/Time 2018/04/14 11:59:56.

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