Experimental Study of Heat Transfer Characteristics and Thermal Efficiency of Different Cooking Pots

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***Abstract* – Nowadays, mostly people uses liquefied petroleum gas (LPG) as a fuel for cooking purpose. In LPG cooking large amount of energy wasted during the cooking process. Therefore, it is important to use the heat energy effectively. This study investigates the heat transfer characteristics and thermal efficiency of cooking pots with water boiling test. The project work involves the five different height to diameter ratio of cylindrical shape of cooking pots are heated with changing the heating time as 5 minutes, 7.5 minutes and 10 minutes. It is found that from the results the pot 2 has highest efficiency of 53.20% for 7.5 minutes of heating time and pot 5 has lowest efficiency of 29.62% for 5 minutes of heating time among the pots. The water boiling test results shows that the pot2 and pot3 required less time to reaches the water boiling temperature among the cooking pots. So pot2 and pot3 are most effective cooking pots. The goal of this study is to determine the thermal efficiency of cooking pots and select the optimum shape of cooking pot. This will help to reduce the heat losses and large amount of energy is to be saved.**

***Keywords*: Water Boiling Test, Heating time, Thermal efficiency, Conservation of energy.**

I. INTRODUCTION

Cooking is an inevitable part of daily life for many reasons such as to reduce food-borne illnesses, and to enhance taste, texture, digestibility. Pots and utensils used for cooking and food preparation typically work on LPG gas, coal, biomass, or electric stoves. LPG gas is the most used energy source. Kitchens are one of the places where deals with this phenomenon daily in cookware application. This leads us to two considerations: thermal diffusivity and reactivity. Thermal diffusivity determines how fast the pan will heat up. Several studies about energy efficiency in cooking pots have focused primarily on the stove type and the type of fuel used. They studied the heat transfer characteristics of different sauce pans on various cooktops such as electric coil, natural gas and induction cook tops and identified the most appropriate sauce pan for each cooktops. Differences in cooking efficiencies are due to differences in heating principles and cook top wattage, pan size and shape, composition, base thickness and mass [2]. The cooking efficiency is determined based on various parameters such as loading weight, loading height and mass of water added into the pot. The carbon emissions during cooking process is measured at different power levels [3]. The analysis of temperature distribution is done with two different structures of cooking utensils and compare the insulated and non insulated cooking utensils[4].The comparison of heat transfer efficiency of flat bottom surface and rounded bottom surface of cooking pots. The rounded bottom pot have higher heat transfer efficiency than flat bottom cooking pot [5]. The combustion efficiency of stoves using biomass as a fuel in rural areas without access to an electrical interconnection system or natural gas network. They created a baseline for calculating greenhouse gas emissions, particulate matter emissions, and combustion efficiency and proposed an efficient operating range according to the power and dimensionless criteria [6-8].

II. MATERIALS AND EXPERIMENTAL METHODS

1. Water boiling test.

Water boiling test is conducted for calculating thermal efficiency of cooking pot.

The following experimental procedure is employed during test :

1. Initially measure the weight of the cooking pot without water.
2. Add some amount of water in the pot.
3. Measure the weight of pot with water.
4. Measure the initial temperature of water.
5. Turn on the LPG stove.
6. Start the test by putting the pot on stove and begin to record the time.
7. Record the water temperature by thermometer.
8. Record the time when the water reaches the boiling point temperature.
9. After reaching boiling point temperature turn off the lpg stove.
10. Remove the pot from the stove.
11. Finally measure the weight of the pot with the water.

Fig. 1. Experimental setup

Calculation of Thermal efficiency of cooking pot

Thermal efficiency of cooking pot is the ratio of energy entering into the cooking pot to the energy supply from the source to the cooking pot.

$$\eta_{th} = \frac{m_w * C_p * (T_f - T_i) + m_{w,evap} * h_{fg}}{M_f * CV}$$

where,

m_w = Mass of water in Kg.

C_p = Specific heat of water in KJ/KgK.

= 4.187 KJ/Kg K.

T_i = Initial temperature of water.

T_f = Final temperature of water.

$M_{w,evap}$ = Mass of water evaporated in Kg

h_{fg} = Specific latent heat of water in KJ/Kg.

M_f = Mass flow rate of LPG gas in Kg /sec.

CV= Calorific value of LPG gas in KJ/Kg.

Table 1. Density and thermal properties of different cooking pot materials [4].

Material	Symbol	Density ρ, kg/m^3	Thermal conductivity K, (W/M K)
			T = 400K
Copper	Cu	8933	393
Aluminum	Al	2700	240
Stainless Steel	SSt	8055	17.3
Chromium Nickel	Cr-Ni	8400	14
Titanium	Ti	4500	20.4

Table 2. Cooking Pots details.

Cook Pot	Material	Diameter (cm)	Height (cm)	Volume (cm^3)
Pot 1	Stainless Steel	10	25	2000
Pot 2	Stainless Steel	15	12	2000
Pot 3	Stainless Steel	20	6	2000
Pot 4	Stainless Steel	25	4	2000
Pot 5	Stainless Steel	30	3	2000

Different types of cooking pots is shown in fig 2 – 6.

1. Pot 1

Fig. 2. Pot 1

2. Pot 2

Fig. 3. Pot 2

3. Pot 3

Fig . 4. Pot 3

4. Pot 4

Fig. 5. Pot 4

6. Pot 5

Fig. 6. Pot 5

III. OBSERVATIONS

Table 3. Heating test of cooking pots for 5 minutes time duration on full flame of gas.

	BEFORE TEST				AFTER TEST			
Cook Pots	**Height to Diameter Ratio of Pots**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Efficiency (%)**
Pot 1	0.13	4230	29	2380	4208	84	2350	40.78
Pot 2	0.20	4208	29	2405	4186	84	2370	41.89
Pot 3	0.35	4186	29	2065	4164	84	2040	39.66
Pot 4	0.80	4164	29	2060	4142	80	2055	32.728
Pot 5	2.60	4142	29	2120	4120	75	2115	29.62

Table 4. Heating test of cooking pots for 7.5 minutes time duration on full flame of gas.

	BEFORE TEST				AFTER TEST			
Cook Pots	**Height to Diameter Ratio of Pots**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Efficiency (%)**
Pot 1	0.13	4375	29	2380	4345	96	2260	50.08
Pot 2	0.20	4345	29	2405	4320	96	2320	53.2
Pot 3	0.35	4320	29	2065	4290	96	1955	48.44
Pot 4	0.80	4290	29	2060	4260	96	2020	36.99
Pot 5	2.60	4260	29	2120	4230	96	2115	31.27

Table 5. Heating test of cooking pots for 10 minutes time duration on full flame of gas.

	BEFORE TEST				AFTER TEST			
Cook Pots	**Height to Diameter Ratio of Pots**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Weight of gas Cylinder (gm)**	**Temp. (°C)**	**Weight of pot + water (gm)**	**Efficiency (%)**
Pot 1	0.13	4455	28	2380	4415	96	2180	47.71
Pot 2	0.20	4415	28	2405	4375	96	2200	48.32
Pot 3	0.35	4530	28	2065	4490	96	1875	46.48
Pot 4	0.80	4570	28	2060	4530	96	1930	39.12
Pot 5	2.60	4490	28	2120	4455	96	2065	34.20

IV. RESULTS AND DISCUSSIONS

A. Results for heating test

1. Heating test of cooking pots for 5 minute time duration on full flame of gas.

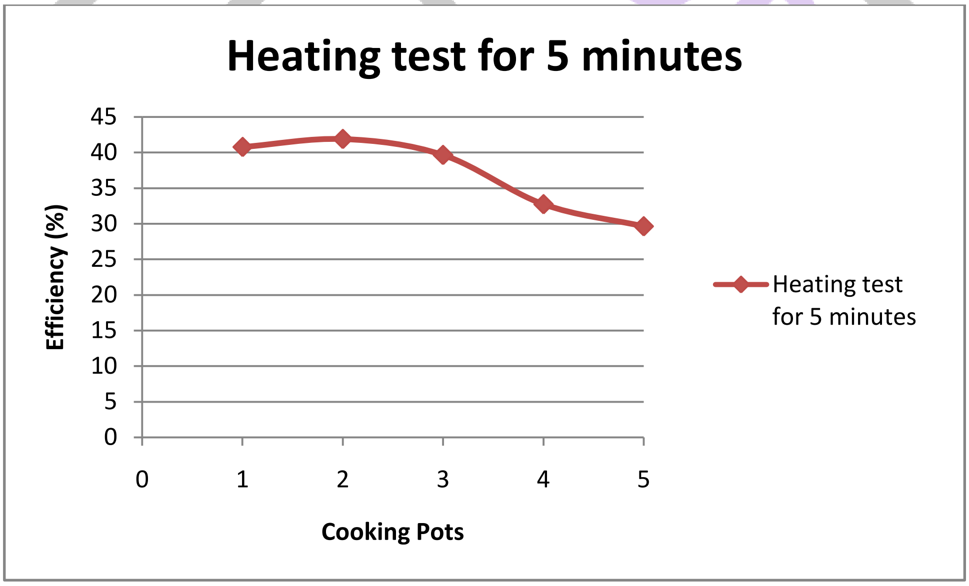

Fig. 7. Thermal Efficiency of Cooking Pots for 5 minute time period.

Heating test of cooking pots for 7.5 minute time duration on full flame of gas.

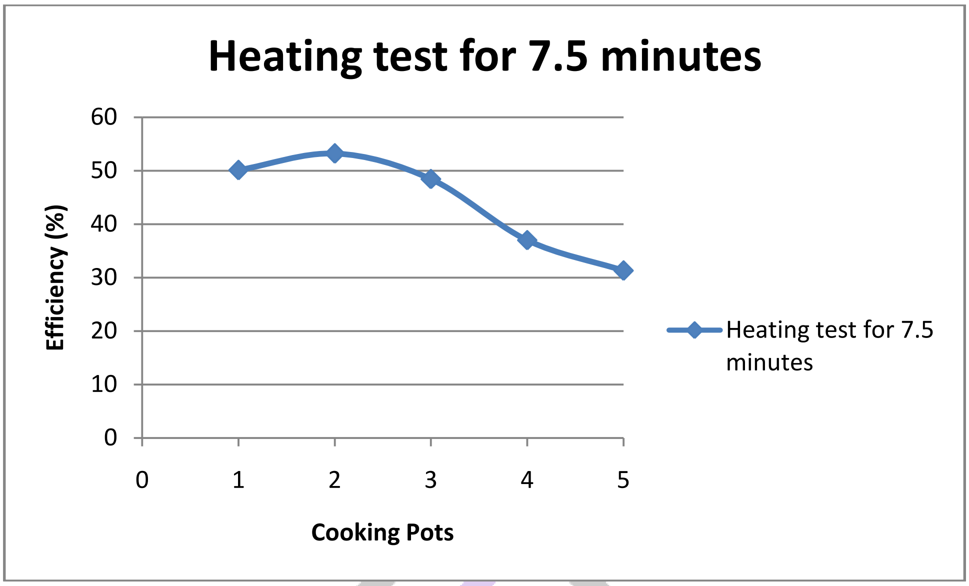

Fig. 8. Thermal Efficiency of Cooking Pots for 7.5 minute time period.

3.Heating test of cooking pots for 10 minute time duration on full flame of gas

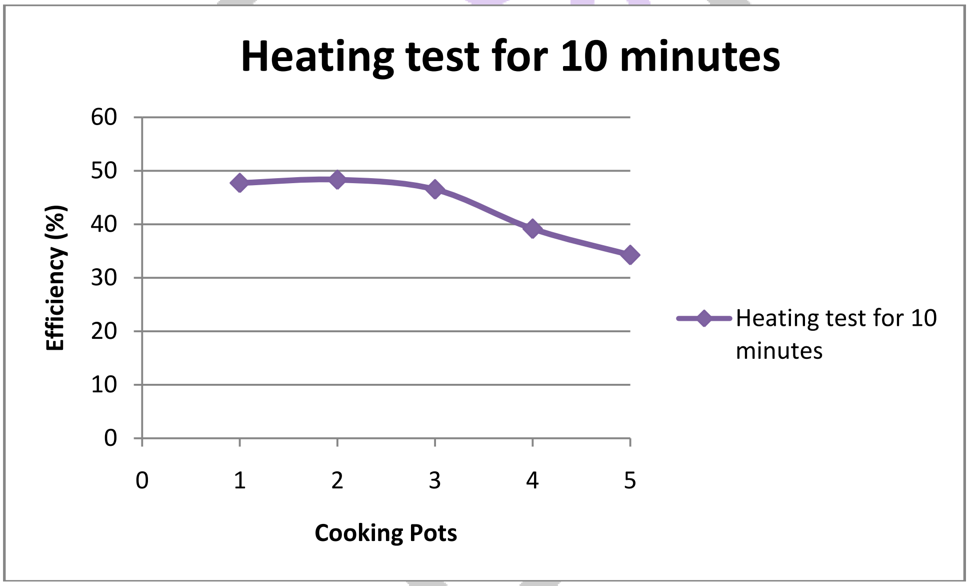

Fig. 9. Thermal Efficiency of Cooking Pots for 10 minute time period

Results of thermal efficiencies during heating test are shown in Fig. 7, Fig. 8 and Fig 9. It shows that the Pot 2 has highest thermal efficiency of 41.89%, 53.20% and 48.32% at full flame gas flow rate for heating time of 5 minute, 7.5 minute and 10 minutes respectively. Pot 5 has lowest thermal efficiency of 29.62%, 31.27 % and 34.20 % at full flame gas flow rate for heating time of 5 minute, 7.5 minute and 10 minutes respectively. In case of Pot 2 the height to diameter ratio is optimum so thermal efficiency is highest. In case of Pot 5 conduction losses are more since lot of amount of energy is used for heating pot only so thermal efficiency is lowest.

B. Results for water boiling test

Water boiling test is a simple comparison test in which time required by different pots for water boiling is calculated.

Procedure:

1. Five pots are selected of different h/d ratio.
2. 1.5 kg of water is filled with pot.
3. For every 30 seconds temperature of water is recorded with the help of thermometer.

4. As soon as temperature is reached 98^0 total time is recorded.

Calculations of boiling point temperature.
Air pressure above sea level can be calculated as

$P = 101325 (1 - 2.25577 \times 10^{-5} H)^{5.25588}$

Where,

101325 = Normal temperature pressure at sea level (Pa)

P = Air pressure (Pa)

H = Altitude above sea level (m)

H = 560 m at Pune.

$P = 101325 (1 - 2.25577 \times 10^{-5} \times 560)^{5.25588}$

P = 94776 Pa =0.94776 bar

Then from steam table saturation boiling point of water is calculated as

Pressure (bar)	Temperature (°C)
0.90	96.71
0.95	98.20

By interpolation we get boiling point = 98.12 °C

Table 6. Temperature Variation during water boiling test for every 30 seconds.

Time in sec	pot 1	pot 2	pot 3	pot 4	pot 5
0	28	28	28	28	28
30	31	31	33	33	33
60	35	33	36	36	36
90	38	36	40	39	40
120	42	39	44	43	44
150	44	42	49	47	47
180	47	46	53	52	51
210	50	49	55	55	54
240	53	52	57	59	58
270	56	55	59	62	61
300	59	58	63	64	65
330	62	61	66	67	68
360	65	64	70	70	70
390	67	67	72	72	72
420	70	69	74	75	74
450	72	72	77	77	75
480	75	75	79	79	77
510	78	77	82	81	79
540	80	80	84	83	81
570	83	83	86	86	83
600	85	86	88	88	84
630	88	89	91	90	86
660	91	92	93	91	88
690	93	95	94	92	90
720	95	96.5	96	93	91
750	96	96.5	97	94	92
780	96.5	97	97	94.5	93
810	97	97	97	95	93.5
840	97	97	96.5	95.5	94.5
870	97.5	97.5	97	96	95
900	97.5	97.5	97	96.5	96

930	97.5	98	97.5	97	96.5
960	98	98	97.5	97	96.5
990	98	98	97.5	97.5	97
1020	98	98	98	97.5	97
1050	98	98	98	97.5	97.5
1080	98	98	98	98	97.5
1110	98	98	98	98	97.5
1140	98	98	98	98	98
1170	98.5	98	98	98	98
1200	98.5	98.5	98	98	98

Graphical results of Water Boiling Test.

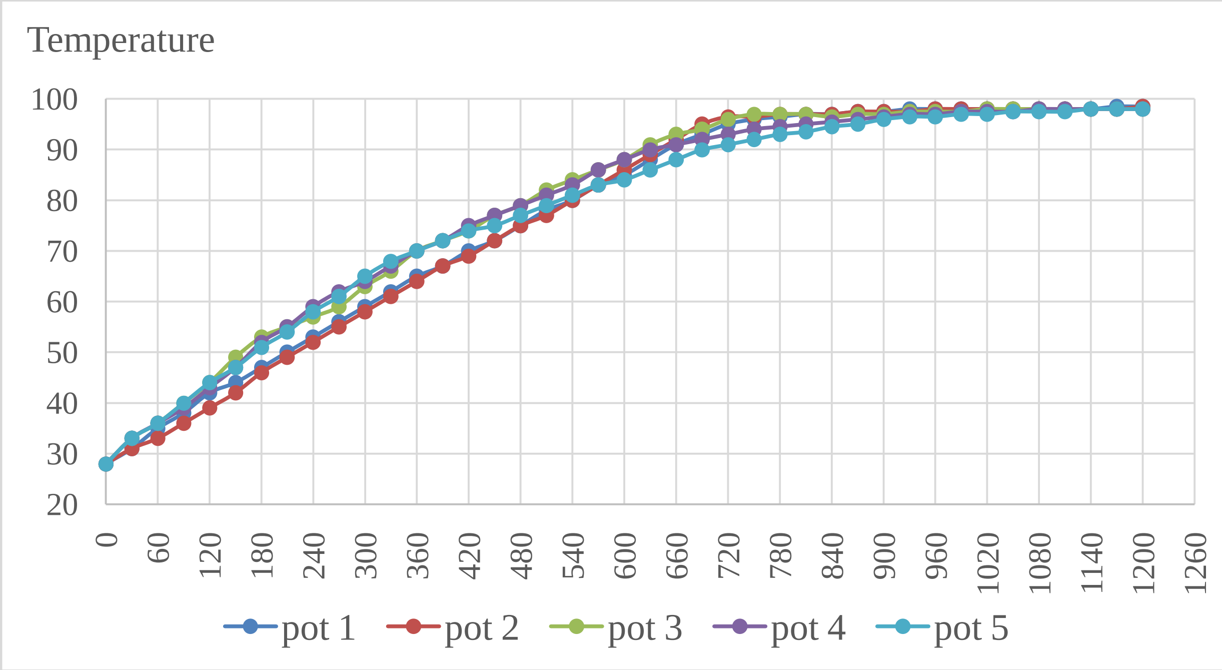

Fig. 10. Temperature variation during water boiling test.

The temperature variation during water boiling test is shown in fig. 10. The Pot 2 and Pot 3 requires lesser time to reach the boiling point than other pots since radiation losses are lesser in these pots due to compact geometry. Pot no.5 has more conduction & radiation losses than other cooking pots. So it requires highest time to reach the boiling point temperature.

CONCLUSIONS

This study investigates the heat transfer characteristics and thermal efficiency of cooking pots with water boiling test. It is found that from the results the pot 2 has highest efficiency of 53.20% for 7.5 minutes of heating time and pot 5 has lowest efficiency of 29.62% for 5 minutes of heating time among the pots. The water boiling test results shows that the pot2 and pot3 required less time to reaches the water boiling temperature among the cooking pots. So pot2 and pot3 are most effective cooking pots and Pot 5 required more time to reach the water boiling temperature. Conduction losses are more in case of Pot 5 since lot of amount of energy is used for heating pot only so it takes more time for boiling water. The convection and radiation losses are less in case of Pot 2 and Pot 3 due to the optimum Height to diameter ratio so thermal efficiency is highest among the cooking pots hence the large amount of heat energy has to be saved during cooking process.

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