ENHANCEMENT IN THE PERFORMANCE OF LPG STOVE THROUGH CFD ANALYSIS

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ABSTRACT
Abstract- Industry depends on heat from the burners in all ignition system. Upgrading burner execution is basic to consenting to tough discharges prerequisites and to improve mechanical efficiency. Indeed, even little upgrades in burner vitality effectiveness and execution can have huge effects in a constant activity, all the more so if the enhancements can be utilized in other ignition system and across businesses. To perform Computational Fluid Dynamics recreation offers a numerical demonstrating philosophy that helps in such manner. In the current work, computational models are utilized for the investigation of various methods of ignition and furthermore to consider the two sorts of utensil in particular round and flat shape for gap spacing, flame flow rate and fire size of the burner to get the ideal productivity. In test and CFD recreation limit condition with two utensils (flat level and round) base are utilized to think about the best ideal model for effective utilization of LPG. Henceforth, approval of test and numerical outcomes are to be performed.
Keywords: ANSYS Fluent, CATIA, CFD, Burner, Utensils

I. Introduction
The massive consumption of fossil energies for energy requirements results in environmental impurity and an advanced rate of resource reduction because of the rapid-fire growth of assiduity, profitable development and the elaboration of humans. Numerous countries are invested in chancing indispensable sources of clean energies because environmental pollution has increased extensively due to the overuse of fossil energies. In developing countries, cooking consumes a significant portion of energy demand, and perfecting the effectiveness of marketable LPG ranges can have a global impact on energy utilization and reduce environmental pollution from fossil energies. Regarding LPG consumption, India ranks as the second largest country encyclopaedically and has paid a huge quantum for subsidizing around33.76 billion USD in the last decade (8). In the financial time 2022 – 23, the Indian government extended a subvention of Rs. 200 per14.2 kg LPG cylinder to all consumers, including those under the Pradhan Mantri Ujjwala Yojana(PMUY) program. still, no similar subvention has been blazoned for the financial time 2023–24.Accordingly,this absence of subvention has redounded in a significant rise in the price of a14.2 kg LPG cylinder in Delhi, reaching Rs. 999 on September 10, 2023, compared toRs.769 in the antedating time, depending upon the state, it'll vary. Considering the increased consumption of LPG, the Indian government needs to examine all possible styles to drop the emigration characteristics of conventional cuisine ranges grounded on LPG and ameliorate thermal effectiveness. Virtually, combustion in an LPG grounded conventional burner (CB) produce stovepipe gas with adulterants like nitrogen oxides (NOx), unburned carbon- hydrogen (CnHm), and carbon monoxide(CO) and has low power modulation capability. Hydrogen is getting decreasingly favored over LPG as a better volition because of its generous, renewable source, lesser energy viscosity, and environmentally friendly manufacturing processes. In discrepancy to LPG, which depends on finite reactionary energy coffers and releases advanced situations of adulterants, hydrogen offers a cleaner, more energy-effective and sustainable energy choice for numerous uses. In the diffusion mode, a diffusion flame may be defined as a non-premixed, quasistatic, nearly isobaric flame in which most of the reaction occurs in a narrow zone that can be approximated as a surface.

In the mixed mode combustion, there's partial premixing of dears as well as prolixity also occurs. Similar dears do in numerous practical operations like in artificial burners; gas- fired domestic burners, rocket burners and also gas turbine combustors. Although overflows in combustors generally are turbulent, analyses of honey stabilization are frequently grounded on equations of laminar inflow. This may not be as bad as it seems because in the regions of the inflow where stabilization occurs, distributed responses may be dominant, since response wastes may not have had time to develop; an approximation to the turbulent inflow might also be attained from the laminar results by replacing laminar diffusivities by turbulent diffusivities in the results.

Numerous of experimenters carried out the study on wood cookstove, kerosene- grounded cookstove, ethanol cookstove and waste cuisine oil painting/ Kerosene mix cookstove. also, among many studied are related on gas cookstove and their performance and emigration products. The performance analysis of domestic LPG cooking ranges with pervious media was carried out. It was set up that the operation of pervious media, the maximum thermal effectiveness of the cookstove is 73. The volume of CO2 increases from0.69 to0.94, while the quantum of CO reduces from 225 ppm to 118 ppm. Energy bring analysis showed a saving of 10. Table 1 illustrates the result of comparison between pervious media burner with conventional burner.

SR.NO	Burner model	Thermal efficiency (%)	Heat utilized in cooking (MJ)	Energy cost in Rs
1	Conventional Burners	67–69	9.6–9.4	>3
2	Metal balls and gravel	68–72	9.4–8.8	<3
3	Metal chips	73	8.5	2.9

Table 1 The result of comparison between porous media burner with conventional burner.

Factors affecting performance of LPG stove

- Pot material
- Pot size
- Pot shape
- Spacing between burner top and vessel bottom.
- Gas flow rate
- Burner

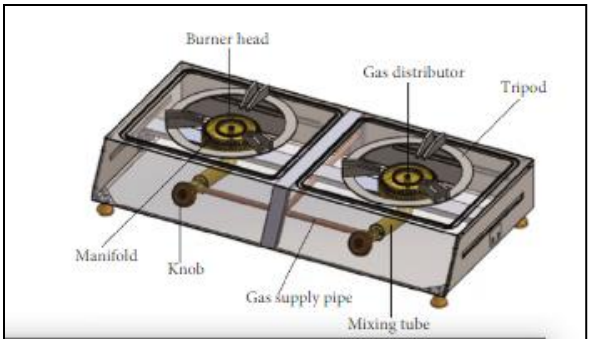

Fig. 1 Components of LPG stove

II. Literature review

Matthujak et al. [1], This study proposes a new modification of the LPG burner (NB-5), combining features from three Thai commercial burners: KB-5, S-5, and EB-5. CFD techniques were used to investigate the benefits of each burner's features. The NB-5 burner increased mixing intensity, primary aeration, generated a swirling central flame, reduced heat loss, and increased secondary aeration, leading to increased combustion temperature and flow velocity, resulting in improved net heat flux. Simulation results showed that the NB-5 burner produced the highest average temperature of 929.35 K and the highest heat flux of 58.01 kW/m^2, resulting in enhanced thermal efficiency. The study highlights the benefits of using CFD simulations in designing and modifying LPG burners, allowing manufacturers to design and optimize burners more effectively at a lower cost than traditional water boiling tests.

Wichangarm et al. [2], This study presents a new system for prognosticating the thermal effectiveness of an LPG- energy saving burner (EB) using computational fluid dynamics (CFD) data. The system uses identified data from experimental measures and numerical heat flux to estimate the EB's thermal effectiveness. The study investigates the goods of LPG released- pressure on inflow marvels and thermal effectiveness. The correlation equation is presented, chancing a difference of around ±2.41 between the calculated and experimental data. Two advanced performances of the EB burner, EB-W and EB-WT are presented and estimated numerically. The prognosticated thermal edges are 9.02 and 7.87 advanced than the original EB burner, attesting the system's effectiveness in assessing and enhancing burner effectiveness.

Aravindan et al. [3], Liquefied petroleum gas (LPG) is rapidly gaining popularity due to its various applications, including industry and domestic use. Hydrogen-blended LPG (H2-LPG) fuels offer reduced emissions and increased fuel efficiency, while hydrogen is a promising option due to its clean-burning properties and easy transportation. A study examining the combustion performance of blended fuels of hydrogen and LPG for commercial cooking burners (CCBs) found that blending hydrogen with LPG up to 50% can significantly improve combustion performance, reduce CO and CO2 emissions, and increase economic viability through fuel conservation.

Gohil et al. [4], The study investigates the efficiency, heat conservation, and emission products of Liquefied Petroleum Gas (LPG) cooking stoves without and with a flame shield method. The results show that the thermal efficiency of a conventional burner without a flame shield is 66.27%, while with a flame shield, the maximum efficiency is 74.07%. The maximum temperature gain and heat generation increase by 2.1% and 3.0%, respectively. The emission test shows a decrease in CO2 from 0.9% to 3.8% and less NOx and HC than without a flame shield burner. The study concludes that using a conventional gas stove burner with a flame shield offers better economic and environmental compatibility.

Okino et al. [5], The study aims to ameliorate the performance of a cuisine cookstove in developing countries by using sawdust as a sequestration material. A 26 cm saucepan periphery cookstove prototype was designed and constructed with sawdust and complexion in a 11 rate and sawdust alone as the alternate subcaste. The cookstove's thermal effectiveness was assessed using indigenous wood energies from pastoral Uganda and computational fluid dynamics was used to pretend temperature and haste fields within the combustion chamber. The cookstove remained cold as hot air was confined to the combustion chamber, with haste inflow remaining constant. A thick subcaste of 6 cm or further could ensure good sequestration, and further sawdust could further reduce heat flux. The cookstove has the implicit to reduce biomass consumption and emigrations compared to traditional ranges. Farther studies should concentrate on minimizing the consistence of the complexion- sawdust sub caste and adding the consistence of the sawdust sub caste to reduce the cookstove's weight.

Alfarraj et al.[6],The traditional Bunsen burner for the Saudi LPG/air mixture had an operation problem, particularly in a lean mixture. A modified Bunsen burner was developed to overcome these limitations and achieve a stable flame. The equivalence ratio ranges were between 0.68 and 1.30 using the modified burner. A MATLAB algorithm was applied for flame image processing and

measuring laminar burning velocity. The laminar burning velocity was found to be 35 ± 0.91 cm/s under stoichiometric conditions, with a half-cone angle of 16.20 ± 0.76° and a minimum flame height of 21.50 ± 0.22 mm above the Bunsen burner exit.
Gao et al.[7],Cooking is a daily activity that consumes energy and produces pollution. Using clean gas fuels instead of traditional solid fuels can significantly reduce air pollution. Early domestic gas cookers had poor thermal performance, but small improvements can result in significant energy savings. Research into developing domestic gas stoves to improve performance and reduce energy consumption is ongoing. The use of hydrogen-enriched natural gas as an environmentally friendly fuel is also increasing. This paper performs descriptive statistics and graphical visualization of network analysis using common databases and Bibliometrix. It analyzes the energy balance of domestic gas stoves and the influence of single and multiple factors on stove performance. The paper provides an overview of research technologies enhancing gas stove thermal performance, discusses research progress and application prospects, and identifies areas for future research.
Teotia et al.[8],The study investigates the impact of porosity and loading height on the performance of domestic gas burners using LPG as fuel. The Water Boiling Test (Version 4.2.3) is used to determine the thermal efficiency of the stove. Results show that increasing the number of holes in intermediate and innermost rows reduces pitch by 58% and 65% respectively. Increased porosity increases thermal efficiency in hot and cold phases by about 30% and 26% in simmer phases. The study also identifies an optimum loading height for the LPG cookstove (1-3 kW) for cold and hot phases. However, the thermal efficiency decreases significantly when running the stove with a stand (11.25 mm) compared to the optimum height (14.1 and 14.6 mm).
Samiran et al.[9],The study investigates the performance of a swirler mechanism that combines axial and radial types of swirlers to reduce emissions and increase mixing process in the non-premixed method. The swirler designed using Solidworks software and CFD analysis performed using ANSYS Fluent software, was used with liquefied petroleum gas (LPG) gas containing 30% propane and 70% butane. The results showed that the combined swirler reduced CO emissions due to higher reaction into CO2 components due to a broader temperature range and higher velocity magnitude. However, the maximum temperature result for the axial swirler was higher than the combined swirler. The study recommends increasing the inclination blade angle in the axial swirler to increase the temperature value.
Dahiya, et al.[10], This review focuses on improving the efficiency and emission features of LPG cook-stoves, including Biogas variants. It considers parameters like performance, efficiency, and emission features, as well as the design factors of burners used. The study found that enhancing stove efficiency requires improving specifications, design, and material of the burner. Air preheating is crucial for better burners, as it increases thermal efficiency and reduces CO and NOX emissions. Porous media burners have higher thermal efficiency, while iron burners are less efficient. The material of the burner also plays a significant role in stove performance, with burners made of ceramics being more efficient than iron burners. The shape of the burner also plays a role in improving stove performance.
Ahmad et al.[11], Biomass is a widely used and widely available resource for cooking and heating, with a significant portion of the Asian population relying on solid biomass. However, traditional cookstoves (TCS) with less thermal efficiency produce harmful emissions like carbon monoxide and particulate matter with aerodynamic diameter ≤2.5 μm.

III. Literature review gap

- The focus of all literature referred is on the no. of holes of the burner and different types of cross sections of the burners.
- The focus is not given on pot distance from burner and pot shape.

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- The gap between burner and pot can be maintained less as much as possible which will provide higher temperature on pot base. The temperature on pot base is less in case of larger gap which will not give better heating to cooking.

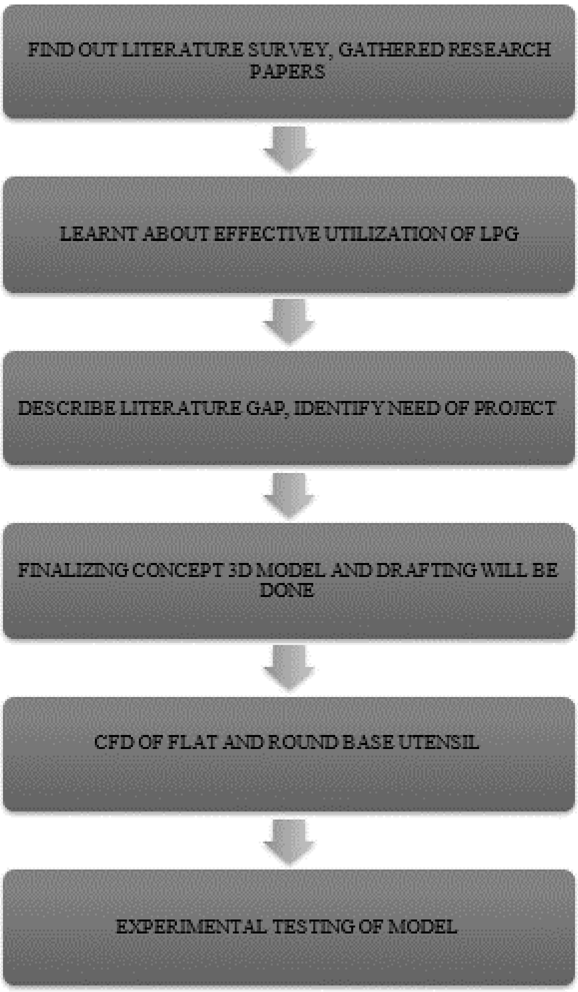
IV. Problem statement

LPG is utilized for cooking in numerous nations for financial reasons, for comfort or in light of the fact that it is the favoured fuel source. It is crucial to make some enhancement for the presentation of standard burners to expand proficiency with generally speaking positive effect on the economy and condition. In present research optimum gap distance between burner and vessel (flat and round) with varying flow rate and flame size is discussed to obtain optimum model for better efficiency.

V. Objectives

1. Design of utensil (round and flat) base in CATIA software.
2. To investigate the effect of operating parameters on performance of burner computationally using CFD simulation.
3. To investigate the effect of operating parameters (varying mass flow rate and spacing between burner and utensil) on performance of burner experimentally and numerically.
4. To investigate the effect of spacing between burner top and vessel bottom.
5. To investigate the effect of flow rate of flame size on shape of vessel (flat and round bottom).

VI. Methodology



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VII. Design of different utensils

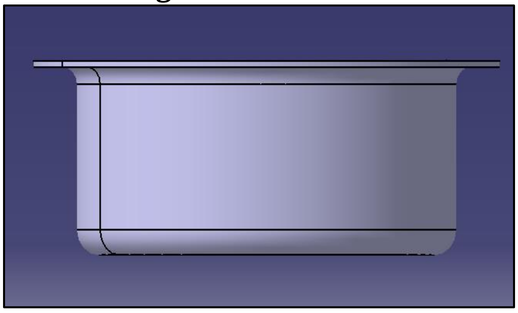


Fig.2 CATIA model of flat base utensil

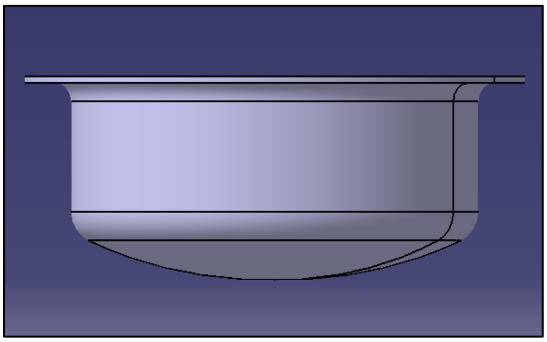
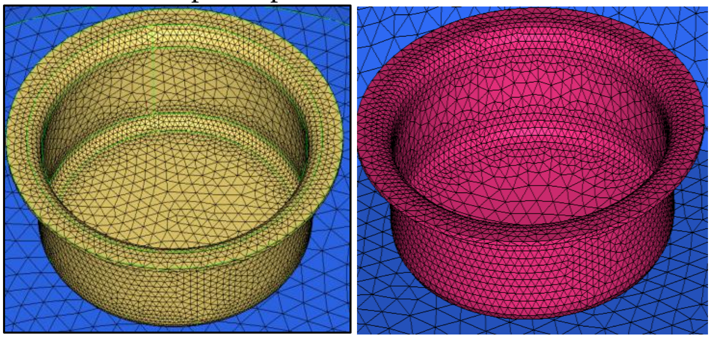


Fig.3 CATIA model of round base utensil

VIII. Computational Fluid Dynamics

Computational fluid dynamics (CFD) Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to dissect and break problems that involve fluid overflows. CFD is now honoured to be a part of the computer- aided engineering (CAE) diapason of tools used considerably moment in all diligence, and its approach to modelling fluid in flow marvels allows outfit contrivers and specialized judges to have the power of a virtual wind lair on their desktop computer.



CFD Procedure

- In CFD simulation bounding box is created across utensil profile for simulation of velocity and pressure distribution across surface of utensil.
- Fine meshing is performed for CFD simulation.
- Named selection is performed in CFD to define air inlet, outlet and surface.
- In general box model gravity is defined in perpendicular direction and energy is kept on to perform conservation of mass, momentum and energy equation to solve.
- Selection of K SST omega turbulence model scalable function along with material as air as fluid and base material for model are selected.
- Hybrid initialization is performed.
- 250 number of iterations is considered.

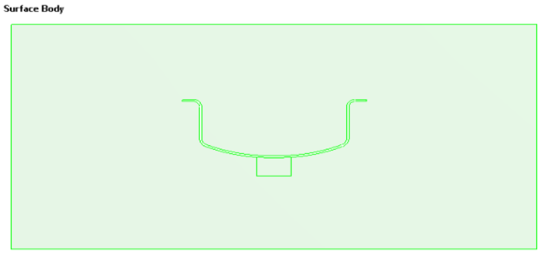


Fig.5 2D axisymmetric geometry for CFD simulation

Mesh

ANSYS Meshing may be a peach- purpose, intelligent, automated high- performance product. It produces the foremost respectable mesh for correct, provident theories results. A mesh well matched for a named analysis may be generated with one click for all rudiments in a veritably model. Full controls over the options habituated induce the mesh are accessible for the professed stoner who needs to fine- tune it. The capability of resemblant processing is automatically habituated reduce the time you have got to stay for mesh generation.

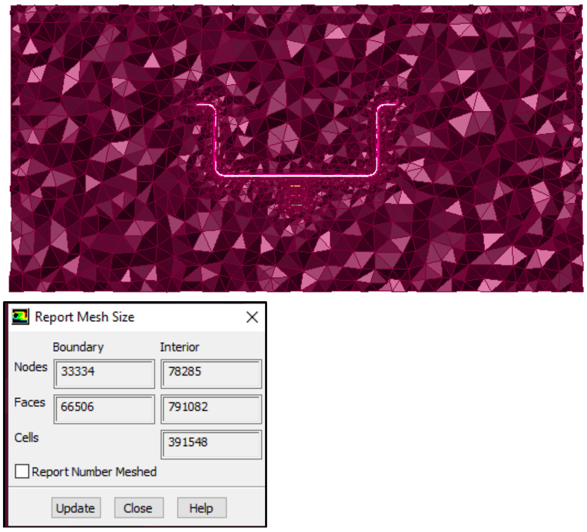


Fig.6 Flat base utensil details of meshing

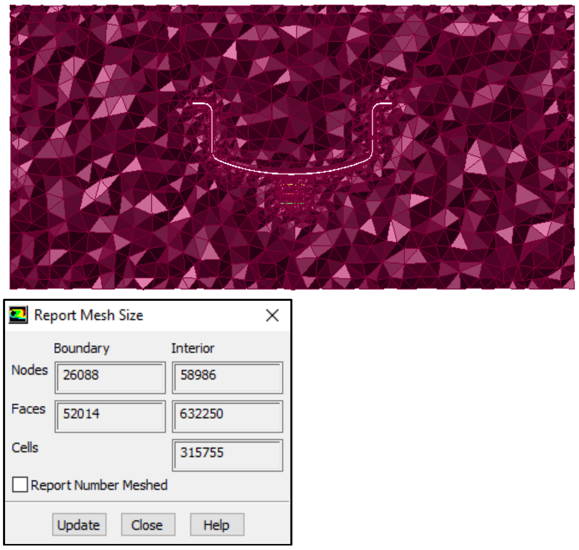


Fig.5 Round base utensil details of meshing

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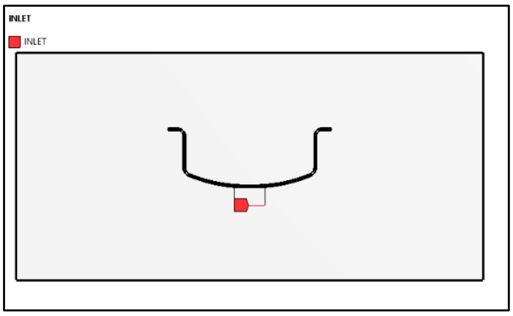

Fig.6 Boundary condition

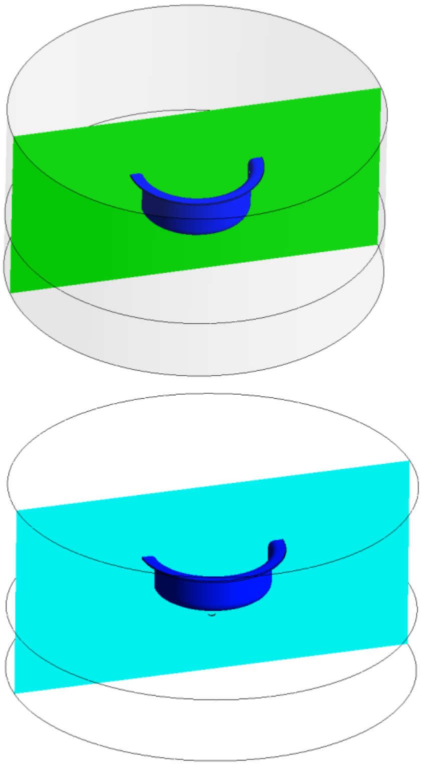
Fig.7 Plane selection for contour

Boundary Condition

A boundary condition for the model is that the setting of a well- known value for a relegation or an associated cargo. For a specific knot you will be suitable to set either the cargo or the relegation but not each. The main kinds of lading accessible in FEA include force, pressure and temperature. These may be applied to points, shells, edges, bumps and factors or ever neutralize from a point.

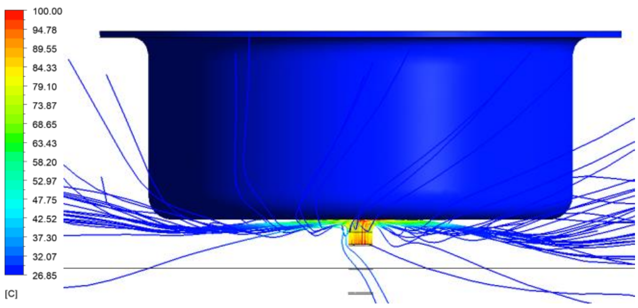

Fig.8 Temperature contour for flat base utensil

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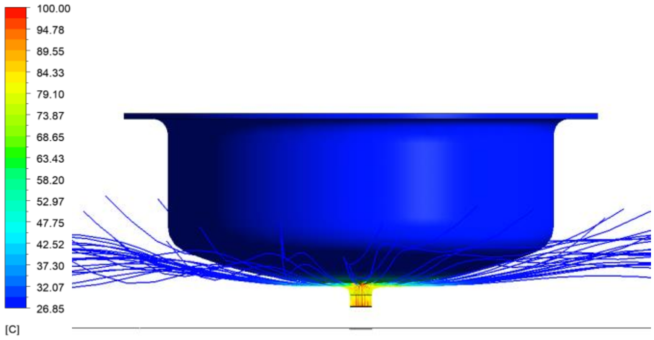

Fig.9 Temperature contour for round base utensil

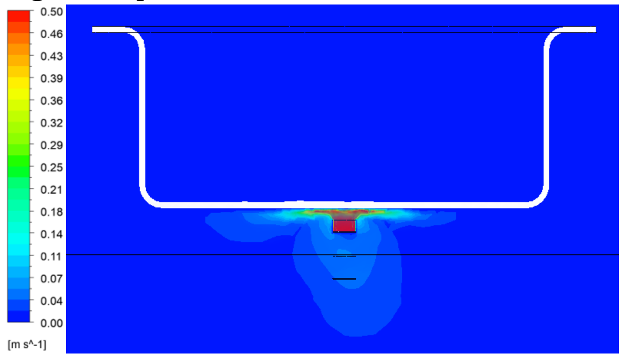

Fig.10 Velocity contour for flat base utensil for 10 mm gap

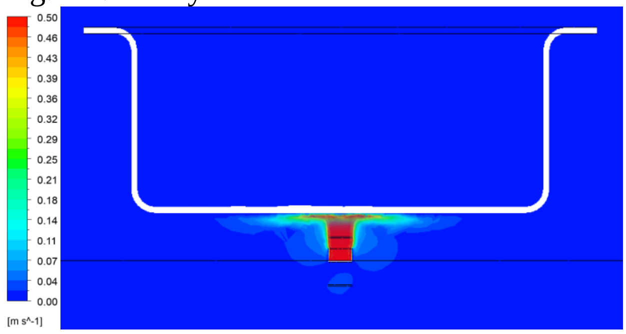

Fig.11 Velocity contour for flat base utensil for 20 mm gap

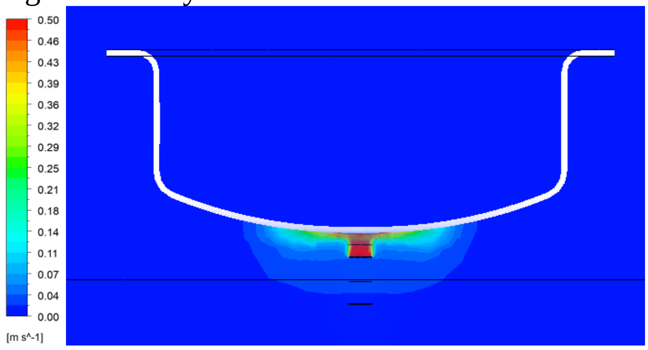

Fig.12 Velocity contour for round base utensil for 10 mm gap

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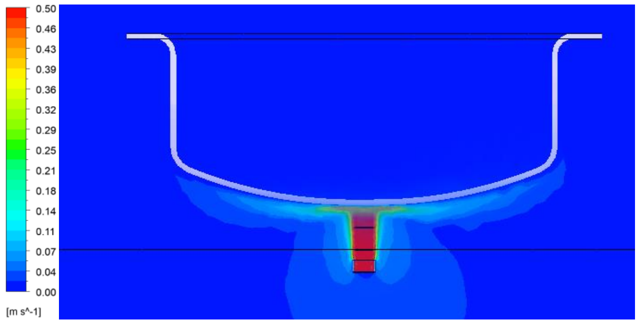

Fig.13 Velocity contour for round base utensil for 30 mm gap

The maximum area of round shaped pot base is covered with hot air as compared to flat base and hence the round base pot is more effective than the flat base pot. The round base directs the hot air to move upward whereas the flat base provides the resistance to hot air flow towards upward and hence the flow is travelling downward direction after hitting flat base of the pot.

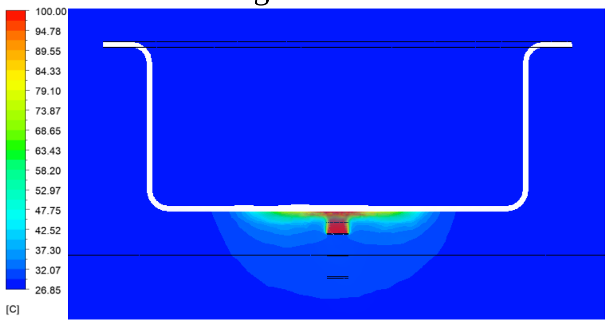

Fig.14 Temperature contour for flat base utensil for 10 mm gap

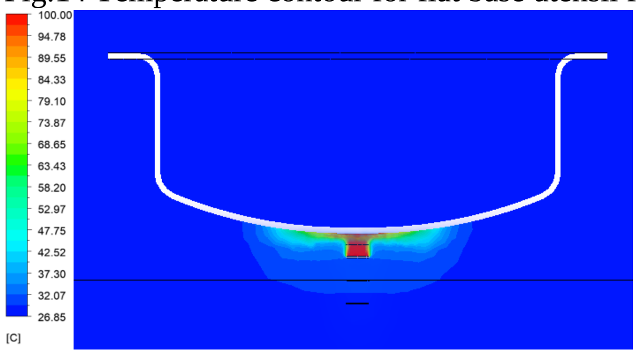

Fig.15 Temperature contour for flat base utensil for 10 mm gap

The increase in gap between pot and burner shows that hot air is covering more area of pot with increased gap. But also note that, it will consume more LPG in larger gap case so as to provide bigger flame. The temperature of pot base is less as compared to lesser gap case and hence it will take maximum time for cooking in case of larger gap in the burner & pot (because of lower thermal gradient between pot & cooking material)

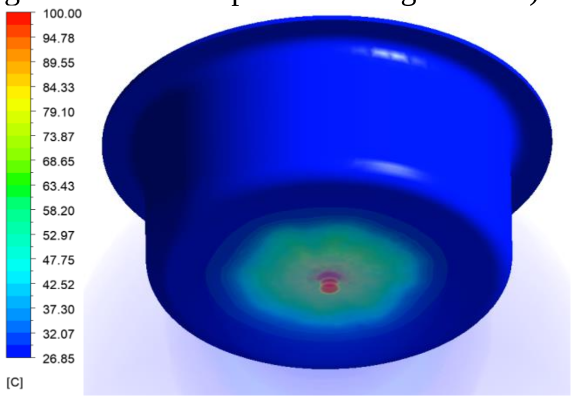

Fig.16 Temperature contour of 3D for flat base utensil for 10 mm gap

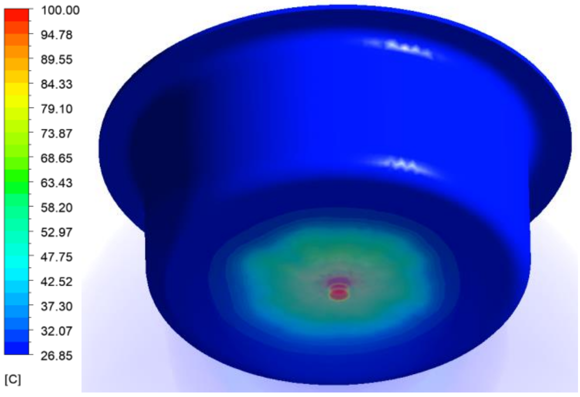

Fig.17 Temperature contour of 3D for flat base utensil for 20 mm gap

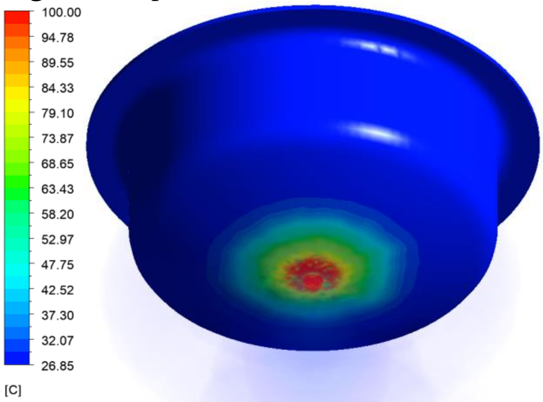

Fig.18 Temperature contour of 3D for round base utensil for 10 mm gap

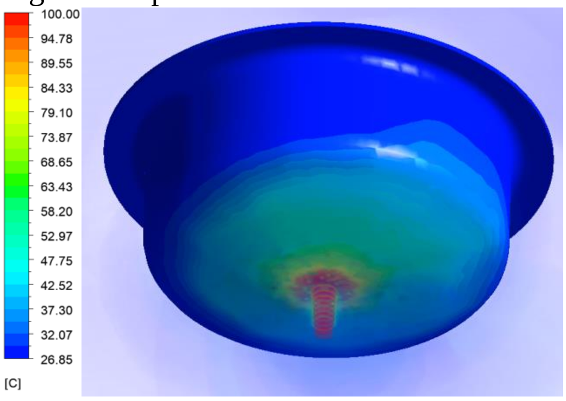

Fig.19 Temperature contour of 3D for round base utensil for 30 mm gap

IX. Experimental Testing

Experimental work

Initially CFD simulation is performed on utensil of two different shapes at bottom namely flat and round bottom to obtain temperature distribution along with distance between burner and utensil to understand parameters in detail.

In experimental two utensil of specified dimension are brought from market and as per CFD simulation boundary condition temperature is measured with thermocouple sensor for each utensil.

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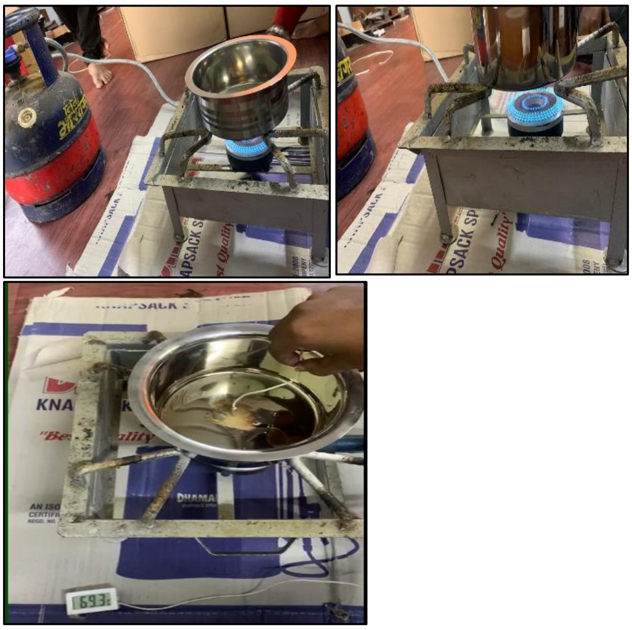

Fig.20 Experimental testing

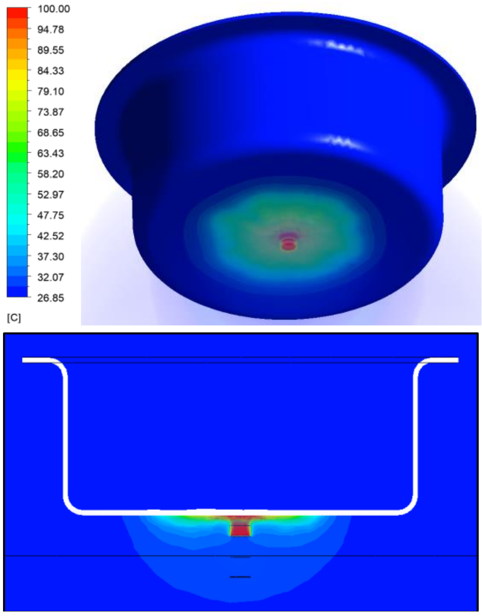

Fig.21 CFD simulation temperature distribution for flat bottom utensil

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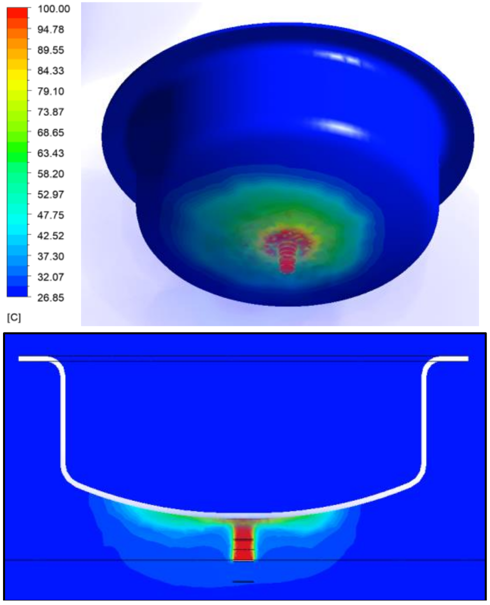

Fig.22 CFD simulation temperature distribution for round bottom utensil

Pot shape	CFD (Temperature distribution) (in ^{O}C)	Experimental (Temperature distribution) (in ^{O}C)
Flat bottom	68 - 73	69
Round bottom	78 - 84	78

Table 2. Comparison of CFD and Experimental Result

- It is observed from CFD simulation that temperature distribution around flat bottom is around (68 – 73) degree Celsius and for round bottom it is around (79 - 84) degree Celsius for same boundary conditions.
- From experimental testing it is observed that temperature distribution around flat bottom is around 69 degree Celsius and for round bottom it is around 78 degree Celsius for same boundary conditions.

X. Conclusion

- The round base pot is more effective than flat base pot. This is because of the maximum area covered by the hot air in round base pot case.
- The gap between burner and pot can be maintained less as much as possible which will provide higher temperature on pot base. The temperature on pot base is less in case of larger gap which will not give better heating to cooking.
- The increase in flame/flow rate will consume maximum LPG and hence it is not efficient to provide maximum flow rate and the design of pot base and gap between burner-pot needs to be optimized for better performance.
- It is observed from CFD simulation that temperature distribution around flat bottom is around (68 – 73) degree Celsius and for round bottom it is around (78 - 84) degree Celsius for same boundary conditions.
- From experimental testing it is observed that temperature distribution around flat bottom is around 69 degree Celsius and for round bottom it is around 78 degree Celsius for same boundary conditions.
- It is concluded that result obtained through CFD simulation and experimental testing are nearly in similar range and are successfully validated.

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