|| Volume 10 || Issue 2 || 2026 || ISSN (Online) 2456-0774 INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS

Experimental Studies on a Forced Draft Domestic Biomass Cook Stove

Dr. K. B. Sutar, Mr. Ankit Pradhan, Mr. Suyog Aanand Roy, Mr. Ved Mistry Mr. Rugved Warlikar

Head of Department, Department of Mechanical Engineering,Bharati Vidyapeeth (Deemed to be University) College of Engineering
Email: kbsutar@bvucoep.edu.in
Undergraduate Students, Department of Mechanical Engineering,Bharati Vidyapeeth (Deemed to be University) College of Engineering
Email: rvwarlikar22-mech@bvucoep.edu.in , saroy22-mech@bvucoep.edu.in ,
apradhan22-mech@bvucoep.edu.in , nmved22-mech@bvucoep.edu.in

* * *

Abstract: This study presents the design, fabrication, and preliminary testing of a forced draft domestic biomass cook stove. Traditional natural draft biomass stoves suffer from incomplete combustion, higher smoke generation, poor flame stability, and low thermal efficiency. To overcome these issues, the proposed stove uses a bottom-mounted fan/blower to supply forced air into the combustion chamber. This improves oxygen availability, air–fuel mixing, combustion stability, and heat transfer. The stove was fabricated using mild steel with insulation support, and its performance was tested using the Water Boiling Test method. The study focuses on fuel consumption, boiling performance, smoke reduction, and thermal efficiency improvement for domestic biomass cooking applications.

Keywords: *Forced draft cook stove; Biomass combustion; Domestic biomass stove; Water Boiling Test; Thermal efficiency; Fuel consumption; Smoke reduction; Air–fuel mixing.*

* * *

I.INTRODUCTION:

Biomass cook stoves are commonly used in rural and semi-urban areas because biomass fuels such as wood, agricultural waste, and briquettes are easily available and economical. However, traditional natural draft cook stoves often suffer from incomplete combustion, excessive smoke generation, higher fuel consumption, and lower thermal efficiency [3], [4], [17], [20]. These problems also create health and environmental concerns due to indoor air pollution [4], [19], [20].

To overcome these limitations, the present study focuses on a forced draft domestic biomass cook stove. In this design, a fan/blower supplies controlled air into the combustion chamber through air vents. This forced airflow improves oxygen availability, air–fuel mixing, flame stability, combustion intensity, and heat transfer performance [1], [7], [8], [13], [22]. Therefore, the proposed cook stove is expected to provide better thermal performance and reduced smoke emission compared with conventional natural draft biomass stoves [4], [10], [13].

II.PROBLEM STATEMENT

Traditional natural draft biomass cook stoves depend only on natural airflow for combustion. Due to this, the oxygen supply inside the combustion chamber is often insufficient and uncontrolled. This causes incomplete combustion, unstable flame, excessive smoke, higher fuel consumption, and lower thermal efficiency [5], [11], [15], [25].

In the previous natural draft stove testing, similar drawbacks were observed, especially poor air–fuel mixing and low thermal efficiency. Therefore, there is a need to develop an improved biomass cook stove with controlled airflow. The present work addresses this problem by using a bottom-mounted fan/blower to force air into the combustion chamber, which can improve combustion quality, heat transfer, and overall stove performance [1], [7], [8], [13], [21], [22].

III. OBJECTIVE OF THE STUDY

The main objective of this study is to design, fabricate, and test a forced draft domestic biomass cook stove for improving combustion performance and reducing the limitations of traditional natural draft cook stoves. The proposed stove uses a fan/blower-assisted air supply system to provide continuous and controlled airflow inside the combustion chamber [7], [8], [13].

The specific objectives of the present work are as follows:

1. To design and fabricate a forced draft biomass cook stove suitable for domestic cooking applications.
2. To improve combustion efficiency by supplying forced air into the combustion chamber using a bottom-mounted fan/blower [1], [7], [21].
3. To provide proper air vents for uniform airflow distribution and better air–fuel mixing inside the combustion zone [5], [6], [23].
4. To reduce smoke generation, incomplete combustion, and fuel consumption compared with traditional natural draft biomass cook stoves [4], [10], [20], [22].
5. To study the flame stability, burning behaviour, and combustion characteristics of biomass fuels under forced draft operating conditions [1], [14], [24], [25].
6. To evaluate the thermal performance of the developed cook stove using the Water Boiling Test method.
7. To develop a low-cost, simple, and user-friendly cook stove design that can be practically used in rural and semi-urban households [18], [19], [20].

Overall, the study aims to show that forced airflow can improve oxygen availability, enhance combustion quality, increase heat transfer, and make biomass cooking more efficient and cleaner for domestic use.

IV. METHODOLOGY

The methodology of this study is based on the design, fabrication, and experimental testing of a forced draft domestic biomass cook stove. First, the limitations of the previously developed natural draft biomass cook stove were studied. The earlier stove showed low thermal efficiency, incomplete combustion, higher smoke formation, and unstable flame behaviour due to insufficient natural airflow [5], [11], [15], [25].

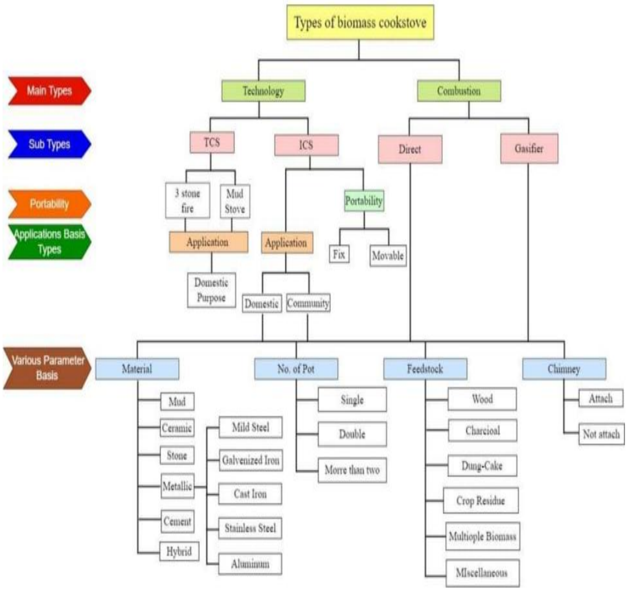

Figure 1 Types of Biomass Cook Stoves

After identifying these limitations, a forced draft system was selected to improve combustion performance. In the proposed design, a fan/blower is mounted at the bottom section of the stove to supply continuous air into the combustion chamber. This forced airflow improves oxygen supply, air–fuel mixing, flame stability, and combustion temperature [1], [7], [8], [13], [21].

The cook stove was designed using CAD modelling. The main components include the combustion chamber, outer body, base plate, air inlet slots, pot support, insulation layer, and blower arrangement. Mild steel was selected for fabrication because of its strength, easy availability, weldability, and low cost [9], [19], [20]. Alumina fiber insulation was used to reduce heat loss and improve heat retention inside the combustion zone [10], [15].

After fabrication, the stove was tested using the Water Boiling Test method. During experimentation, parameters such as fuel consumption, water temperature rise, boiling time, flame stability, smoke generation, and thermal efficiency were observed. The results were then used to evaluate the performance of the forced draft cook stove and compare its improvement over the previous natural draft design.

Design and Fabrication of Forced Draft Biomass Cook Stove

The forced draft biomass cook stove was designed to improve airflow supply, combustion stability, and heat transfer compared with a conventional natural draft stove. The main design idea is to supply controlled air into the combustion chamber with the help of a fan/blower mounted at the bottom section of the stove. This arrangement increases oxygen availability and supports more complete combustion of biomass fuel [7], [8], [13], [22].

The stove consists of a cylindrical combustion chamber, outer body, base plate, air inlet slots, pot support structure, insulation layer, and blower arrangement. The air inlet slots were provided at the base so that forced air can enter the combustion zone uniformly. Proper airflow distribution is important because it improves air–fuel mixing, flame stability, combustion temperature, and heat transfer toward the cooking vessel [5], [21], [23], [24].

Mild steel was selected as the main fabrication material because it is easily available, economical, weldable, and suitable for prototype development. The base plate and outer chamber were made using 5 mm mild steel, while the combustion chamber was made using 3 mm mild steel. Alumina fiber insulation was provided between the inner and outer chamber to reduce heat loss and improve thermal performance [9], [10], [15], [19].

The CAD model of the stove was prepared using Autodesk Fusion 360. The model included the combustion chamber geometry, air inlet slots, pot support, and blower arrangement. After CAD modelling, the components were fabricated using laser cutting, rolling, welding, insulation filling, blower installation, surface finishing, and heat-resistant paint coating. This fabrication approach helped to maintain dimensional accuracy, structural strength, proper airflow passage, and practical usability of the stove.

Experimental Testing Using Water Boiling Test

The experimental testing of the developed forced draft biomass cook stove was carried out by using the Water Boiling Test (WBT). The purpose of this test was to evaluate the thermal performance, fuel consumption, temperature rise, combustion stability, and overall working performance of the stove. The stove was operated under forced draft condition by using a blower fan, which supplied continuous airflow into the combustion chamber.

The Water Boiling Test was performed using biomass fuels such as mango wood and cow dung. During the test, a fixed quantity of water was placed in the vessel and heated by burning the selected biomass fuel. The initial and final temperatures of water were recorded. The mass of fuel consumed was also measured. These values were used to calculate the thermal efficiency of the forced draft biomass cook stove.

The blower-assisted airflow improved oxygen supply inside the combustion chamber. This helped to improve air–fuel mixing, flame stability, heat generation rate, and combustion efficiency. The test was also useful for comparing the performance of the forced draft stove with the previous natural draft biomass cook stove.

Experimental Procedure

1. The stove was cleaned and ash particles were removed before starting the test.
2. A measured quantity of water was placed in the vessel.
3. The initial mass of biomass fuel was recorded.
4. Temperature measuring devices were placed at required locations.
5. The blower system was connected to the air inlet arrangement.
6. Biomass fuel was ignited using small fuel pieces.
7. After flame stabilization, the blower fan was switched ON.
8. The stopwatch was started and the heating process was observed.
9. Temperature readings were recorded during the boiling phase.
10. At the end of the test, the remaining fuel was measured.
11. Thermal efficiency was calculated using the Water Boiling Test method.

Table 1: Previous Natural Draft Cook Stove Test Results

Test	**Thermal Efficiency (%)**
Test 1	14.86
Test 2	15.14
Test 3	14.63
Average Efficiency	14.87

The previous natural draft cook stove showed an average thermal efficiency of 14.87%. This lower efficiency was mainly due to limited airflow, poor air–fuel mixing, incomplete combustion, unstable flame behaviour, and higher heat losses.

Table 2: Observation Table for Mango Wood as Fuel

Parameter	**Fan Speed 1 Test 1**	**Fan Speed 1 Test 2**	**Fan Speed 2 Test 1**	**Fan Speed 2 Test 2**	**Fan Speed 3 Test 1**	**Fan Speed 3 Test 2**	**Fan Speed 4 Test 1**	**Fan Speed 4 Test 2**	**Fan Speed 5 Test 1**	**Fan Speed 5 Test 2**
Weight of water (kg)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Specific heat of water (kJ/kg°C)	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186
Mass of vessel with lid (kg)	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Specific heat of aluminium (kJ/kg°C)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Mass of fuel consumed (kg)	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
Initial temperature of water (°C)	23	23	23	23	23	23	23	23	23	23
Final temperature of water in vessel 1 (°C)	95.6	94.6	95	95.4	94	96	95	94.3	96	95.3
Final temperature of water in vessel 2 (°C)	94.9	95	96	96.5	95.6	94.6	96.6	95.6	95.8	95.8
Final temperature of water in vessel 3 (°C)	96.2	95.2	96.3	96.2	95	94	96	95.4	95.3	94.7
Final temperature of water in vessel 4 (°C)	40.2	44.6	50.3	50.6	44.6	44	29.4	31.7	NA	NA
Efficiency (%)	33.92	34.40	37.08	37.56	33.41	33.87	30.65	31.09	26.11	26.57

Table 3: Average Efficiency for Mango Wood

Fan Speed Level	Experiment 1 Efficiency (%)	Experiment 2 Efficiency (%)	Average Efficiency (%)
1	33.92	34.40	34.18
2	37.08	37.56	37.32
3	33.41	33.87	33.64
4	30.65	31.09	30.87
5	26.11	26.57	26.34

Table 4: Observation Table for Cow Dung as Fuel

Parameter	Fan Speed 1 Test 1	Fan Speed 1 Test 2	Fan Speed 2 Test 1	Fan Speed 2 Test 2	Fan Speed 3 Test 1	Fan Speed 3 Test 2	Fan Speed 4 Test 1	Fan Speed 4 Test 2	Fan Speed 5 Test 1	Fan Speed 5 Test 2
Weight of water (kg)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Specific heat of water (kJ/kg°C)	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186	4.186
Mass of vessel with lid (kg)	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Specific heat of aluminium (kJ/kg°C)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Mass of fuel consumed (kg)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Initial temperature of water (°C)	23	23	23	23	23	23	23	23	23	23
Final temperature of water in vessel 1 (°C)	94.2	94.8	95.4	95.8	95	95.2	94.5	94	94	94.8
Final temperature of water in vessel 2 (°C)	95	95.3	96	96.4	95.4	95.8	94	94.5	94.5	94.7
Final temperature of water in vessel 3 (°C)	72	73.5	94.5	95.2	79	80.4	70.5	71.6	60	61.2
Final temperature of water in vessel 4 (°C)	NA	NA	30.2	31.2	NA	NA	NA	31.7	NA	NA
Efficiency (%)	25.82	26.34	29.91	30.47	28.12	28.66	25.43	25.97	21.88	22.36

Table 5: Average Efficiency for Cow Dung

Fan Speed Level	Experiment 1 Efficiency (%)	Experiment 2 Efficiency (%)	Average Efficiency (%)
1	25.82	26.34	26.08
2	29.91	30.47	30.19
3	28.12	28.66	28.39
4	25.43	25.97	25.70
5	21.88	22.36	22.12

Table 6: Observation Table for Charcoal as Fuel

Parameter	Fan Speed 1 Test 1	Fan Speed 2 Test 1	Fan Speed 3 Test 1	Fan Speed 4 Test 1	Fan Speed 5 Test 1
Weight of water (kg)	4.8	4.8	4.8	4.8	4.8
Specific heat of water (kJ/kg°C)	4.186	4.186	4.186	4.186	4.186
Mass of vessel with lid (kg)	0.51	0.51	0.51	0.51	0.51
Specific heat of aluminium (kJ/kg°C)	0.9	0.9	0.9	0.9	0.9
Mass of fuel consumed (kg)	0.8	0.8	0.8	0.8	0.8
Initial temperature of water (°C)	23	23	23	23	23

Parameter	**Fan Speed 1 Test 1**	**Fan Speed 2 Test 1**	**Fan Speed 3 Test 1**	**Fan Speed 4 Test 1**	**Fan Speed 5 Test 1**
Final temperature of water in vessel 1 (°C)	95.6	96.4	96	95.4	95
Final temperature of water in vessel 2 (°C)	96.2	97	96.6	95.9	95.5
Final temperature of water in vessel 3 (°C)	94.5	96	95.2	90.2	83
Final temperature of water in vessel 4 (°C)	48	60.4	52	42	NA
Efficiency (%)	36.18	39.92	37.84	34.01	30.12

VI.RESULT

From the Water Boiling Test results, it is observed that the forced draft biomass cook stove gives better thermal efficiency than the previous natural draft cook stove. The previous natural draft stove had an average efficiency of only 14.87%. In the forced draft stove, the highest average efficiency for mango wood was 37.32% at fan speed level 2. For cow dung, the highest average efficiency was 30.19% at fan speed level 2. For charcoal, the highest efficiency was 39.92% at fan speed level 2.

The results show that fan speed level 2 gives the best performance for all tested fuels. At this speed, the airflow is sufficient for proper combustion and better heat transfer. At very low fan speed, the oxygen supply is limited. At higher fan speeds, excess air may carry heat away from the combustion zone, which reduces the useful heat transfer to the vessel. Therefore, controlled forced airflow is important for improving the performance of biomass cook stoves.

Overall, the experimental testing confirms that the forced draft arrangement improves oxygen supply, air–fuel mixing, combustion stability, and thermal efficiency. The forced draft biomass cook stove achieved better performance than the natural draft stove and can be considered suitable for domestic biomass cooking applications.

VII.CONCLUSION

The present work successfully designed, fabricated, and experimentally tested a forced draft domestic biomass cook stove.

The main purpose of the study was to overcome the limitations of traditional natural draft biomass cook stoves, such as incomplete combustion, excessive smoke generation, poor flame stability, higher fuel consumption, and lower thermal efficiency [4], [17], [20], [25].

The developed cook stove used a bottom-mounted fan/blower to supply forced air into the combustion chamber. This forced draft arrangement improved oxygen availability, air–fuel mixing, combustion stability, heat generation, and heat transfer toward the cooking vessel [1], [7], [8], [13], [21], [22]. The stove was fabricated using mild steel due to its strength, easy availability, weldability, and economical nature [9], [19], [20]. Alumina fiber insulation was also used to reduce heat loss and improve thermal performance [10], [15].

The performance of the stove was evaluated using the Water Boiling Test method. The previous natural draft biomass cook stove showed an average thermal efficiency of 14.87%. In comparison, the forced draft stove gave much better results. The highest efficiency for mango wood was 37.32% at fan speed level 2. For cow dung, the highest efficiency was 30.19% at fan speed level 2. For charcoal, the highest efficiency was 39.92% at fan speed level 2.

From the experimental results, it is concluded that controlled airflow plays an important role in improving the performance of biomass cook stoves. Fan speed level 2 gave the best performance because it provided sufficient air for combustion without carrying away excessive heat from the combustion zone. At lower fan speed, oxygen supply was insufficient, while at higher fan speeds, excess airflow reduced useful heat transfer.

Overall, the forced draft biomass cook stove showed improved thermal efficiency, better flame stability, reduced smoke formation, and better fuel utilization compared with the natural draft stove. Therefore, the developed stove can be considered a simple, economical, and effective solution for domestic biomass cooking applications, especially in rural and semi-urban areas where biomass fuels are easily available. The study also provides a useful base for further design improvement, airflow optimization, CFD analysis, and emission testing.

VIII.REFERENES

[1] H. S. Mukunda et al., “Design principles and engineering of biomass-based cookstoves,” Current Science, vol. 98, no. 5, pp. 627–638, 2010.

[2] S. C. Bhattacharya, D. O. Albina, and P. A. Salam, “Effects of selected parameters on performance and emission of biomass-fired cookstoves,” Biomass and Bioenergy, vol. 33, pp. 1130–1140, 2009.

[3] J. Jetter and P. Kariher, “Solid-fuel household cookstoves: Characterization of performance and emissions,” Biomass and Bioenergy, vol. 33, pp. 294–305, 2009.

[4] A. K. Gupta and S. C. Roy, “CFD modeling of biomass combustion for cookstove applications,” Renewable Energy, vol. 115, pp. 1090–1102, 2018.

[5] J. Parikh, S. A. Channiwala, and G. K. Ghosal, “A correlation for calculating higher heating value (HHV) from proximate analysis of solid fuels,” Fuel, vol. 84, pp. 487–494, 2005.

[6] M. P. Kshirsagar and V. R. Kalamkar, “A comprehensive review on biomass cookstoves and a systematic approach for design improvements,” Renewable and Sustainable Energy Reviews, vol. 30, pp. 580–603, 2014.

[7] D. Still, N. MacCarty, D. Ogle, T. Bond, and K. Bryden, “Comparing cookstove emissions and performance using standardized testing protocols,” Energy for Sustainable Development, vol. 9, no. 1, pp. 5–15, 2005.

[8] Bureau of Indian Standards, “Biomass Cookstove Testing and Water Boiling Test (WBT) Procedures.”

[9] U. Hayyat, S. S. Ghiwe, M. Shahid, A. Ali, and S. Akhtar, “Experiments and CFD simulation of a biomass cookstove,” Renewable Energy Research Journal, 2019.

[10] R. K. Chauhan, A. K. Sahu, and R. K. Soni, “CFD model simulation and experimental testing of a household husk biomass cook stove,” Biomass and Bioenergy, vol. 120, pp. 112–121, 2020.

[11] U. Hayyat, S. Iqbal, and A. Abbas, “Recent developments and challenges in biomass cookstove,” Renewable and Sustainable Energy Reviews, vol. 134, 2021.

[12] R. Ahmad, H. N. Ilyas, B. Li, M. Sultan, M. Amjad, M. Aleem, A. Abbas, M. A. Imran, and F. Riaz, “Current challenges and future prospect of biomass cooking,” Energy Reports, vol. 8, pp. 1234–1256, 2022.

[13] R. R. Pande, K. A. Seetharamu, and V. Venugopal, “Experimental and CFD analysis to study effect of inlet area ratio,” Biomass Conversion and Biorefinery, vol. 9, pp. 567–576, 2018.

[14] Y. Galindo, M. Contreras, J. Dávalos, and I. Sánchez, “CFD simulation and implementation of a griddle-type biomass stove,” Energy for Sustainable Development, vol. 45, pp. 89–97, 2018.

[15] U. Hayyat, S. Iqbal, and A. Abbas, “CFD simulation of a forced draft biomass cookstove,” Journal of Cleaner Production, vol. 250, 2020.

[16] A. V. Kolge, “Computational study on forced draft biomass cookstove,” International Journal of Engineering Research and Technology, vol. 10, no. 5, pp. 455–460, 2021.

[17] S. Dhakare, P. Sahoo, and K. Bhattarai, “Design optimization of an improved mud cookstove using CFD,” International Journal of Thermal Sciences, vol. 146, 2019.

[18] Himanshu, O. P. Kurmi, S. Jain, and S. K. Tyagi, “Performance assessment of an improved gasifier stove using biomass pellets,” Biomass and Bioenergy, vol. 135, 2020.

[19] R. Kumar, S. Kumar, and A. Kumar, “Design and experimental investigation of a natural draft improved biomass cookstove,” Renewable Energy, vol. 156, pp. 897–906, 2020.

[20] A. Dutta, P. Sarkar, and S. Roy, “Comparative CFD and sustainability assessment of traditional and improved cookstoves,” Sustainable Energy Technologies and Assessments, vol. 52, 2022.

[21] O. A. Akinrinola and F. H. Abdullah, “Performance optimization of hybrid draft biomass cookstove using CFD,” Energy Reports, vol. 7, pp. 3445–3455, 2021.

[22] R. Kshirsagar and V. S. Barve, “Numerical and experimental study on the performance of a biomass cookstove,” Thermal Science and Engineering Progress, vol. 18, 2020.

[23] D. Mutta, W. Gitau, and L. Komba, “Natural-draft flow and heat transfer in a plancha-type cookstove,” Energy Conversion and Management, vol. 171, pp. 1452–1461, 2018.

[24] S. Mehetre and A. T. Chaudhari, “Improved test method for evaluation of bio-mass cook-stoves,” International Journal of Energy Research, vol. 44, no. 7, pp. 5120–5130, 2020.

[25] M. Sedighi and A. A. Alavi Moghaddam, “Comprehensive review of technical aspects of biomass cookstoves,” Renewable and Sustainable Energy Reviews, vol. 119, 2020.

[26] V. S. Barve, R. Kshirsagar, and A. Gudadhe, “User-centric approach for design/sizing of biomass cookstoves,” Energy for Sustainable Development, vol. 61, pp. 45–54, 2021.

[27] M. Kumar, B. Kumar, and R. Singh, “Design, development, and technological advancement in biomass cookstoves,” Renewable Energy Focus, vol. 39, pp. 55–66, 2021.

[28] S. Mehetre and A. Chaudhari, “Improved biomass cookstoves for sustainable development: A review,” Environmental Science and Pollution Research, vol. 28, pp. 33412–33428, 2021.

[29] S. Cassol, P. R. Alves, and J. F. Antoneli, “Optimization of secondary air injection in a wood-burning cookstove,” Applied Thermal Engineering, vol. 196, 2021.

[30] U. Hayyat, S. Iqbal, and M. Amjad, “Performance of hybrid draft biomass cookstove,” Journal of Energy Resources Technology, vol. 143, no. 11, 2021.

[31] K. K. Patil and A. A. Khan, “CFD analysis of improved biomass cookstove geometry,” International Journal of Heat and Mass Transfer, vol. 162, 2020.

[32] S. S. Ghiwe and U. Hayyat, “CFD simulation of a biomass cookstove for combustion efficiency improvement,” Energy Sources Part A: Recovery, Utilization, and Environmental Effects, vol. 43, no. 9, pp. 1045–1056, 2021.

[33] M. Bilal and A. Ali, “Experimental study of energy and emission parameters of natural draft biomass cookstove,” Biomass Conversion and Biorefinery, vol. 12, pp. 221–230, 2022.

[34] Autodesk Inc., “Autodesk Fusion 360: Cloud-based 3D CAD, CAM, CAE, and PCB software platform for product design and manufacturing.”