International Journal of Heat and Technology
Vol. 44, No. 1, February, 2026, pp. 12-18
Journal homepage: http://iieta.org/journals/ijht

The Effect of Flame Holder Thickness Variation on Thermal Performance and Flame Stability in a Meso-Scale Combustor

Nurul Aisyah Ramadhani[1], Achmad Fauzan Hery Soegiharto[1*], Timotius Pasang[2]

[1] Department of Mechanical Engineering, Faculty of Engineering, University of Muhammadiyah Malang, Malang 65144, Indonesia
[2] Department of Engineering Design, Manufacturing and Management Systems, College of Engineering and Applied Sciences, Western Michigan University, Kalamazoo 49001, USA

Corresponding Author Email: achmadfauzan@umm.ac.id

https://doi.org/10.18280/ijht.440102

Received: 10 September 2025
Revised: 28 December 2025
Accepted: 6 January 2026
Available online: 28 February 2026

Keywords:
combustion efficiency, flame holder, flame stability, flammability limit, heat transfer, thickness

ABSTRACT

This study experimentally investigates the influence of flame holder thickness on the thermal performance and flame stability of a meso-scale combustor using butane fuel. Duralumin flame holders with thicknesses of 1.0, 1.5, and 2.0 mm were tested under steady premixed conditions to evaluate temperature distribution, flammability limits, and stability behavior. The results show that decreasing the flame holder thickness enhances heat recirculation and promotes more uniform thermal distribution within the combustor. The 1.0 mm configuration achieved the highest peak temperature (approximately 12–15% higher than the 2.0 mm case) and expanded the flame stability range to equivalence ratios between 1.13 and 1.84. These improvements are attributed to a balanced heat feedback mechanism that minimizes conductive losses while sustaining sufficient thermal energy for flame anchoring. The findings align with previous reports by previous researchers, confirming that excessive wall thickness increases heat dissipation and destabilizes meso-scale flames. The present study provides quantitative experimental evidence linking geometric scaling, specifically flame holder thickness, to meso-scale thermal efficiency and flame stability, offering design insight for a compact combustion and a portable power system.

1. INTRODUCTION

Meso-scale combustors are compact devices designed to sustain combustion within chambers of only a few millimeters in diameter [1]. They received significant attention for their potential in micro- and meso-scale power generation [2], utilizing gaseous or liquid hydrocarbon fuels [3, 4]. Despite these potentials, achieving stable operation remains challenging due to short residence times and pronounced heat losses [5-8]. Consequently, improving understanding of heat transfer mechanisms is crucial to enhancing combustor performance [9, 10]. Recent studies have also highlighted the importance of combustion characteristics and thermal efficiency in energy systems, particularly in relation to temperature distribution and heat utilization within combustion chambers [11, 12].

Flame holders are widely implemented to anchor flames and extend flammability limits [11-15]. Their function relies on promoting thermal recirculation, which preheats reactants prior to ignition [5, 8]. However, their effectiveness is highly dependent on geometric features, with thickness emerging as a critical factor [16, 17]. Excessive thickness increases heat absorption and risks flame quenching [18], whereas insufficient thickness may not sustain enough heat to stabilize combustion [19, 20].

Recent research has emphasized geometric modifications to flame holders as a means of improving combustor reliability. Soegiharto et al. [21] showed that perforated stainless-steel line-type flame holders broadened the stability window compared to hole-type designs by promoting vortex formation and enhanced feedback. Similarly, Sudarman et al. [22] reported that a 7 mm heat recirculation segment improved stability and flame temperature compared to a 10 mm configuration. In line with these findings, Ata and Özdemir [23] examined turbulent non-premixed conical bluff-body flames and confirmed that small variations in flame holder geometry significantly influence stability limits, further underscoring the importance of geometric optimization.

While studies have investigated material choice and overall geometry, the specific effect of thickness variation in duralumin flame holders on stability and thermal efficiency has not been systematically addressed. This work, therefore, evaluates the impact of three thickness levels (1 mm, 1.5 mm, and 2 mm) through experiments in a butane-fueled meso-scale combustor.

Previous research has primarily focused on material selection and general geometry optimization of meso-scale combustors, but relatively few have examined the detailed influence of component thickness on flame stabilization and thermal efficiency. Liu et al. [24] investigated the effects of wall thickness and material on flame stability in a meso-scale combustor with thermally orthotropic walls, showing that thicker walls tend to limit flame holding capability due to enhanced heat loss. Similarly, Peng et al. [25] explored the effect of wall thickness and porous media on a non-premixed hydrogen micro-combustor, demonstrating that reduced wall thickness enhances heat recirculation and improves thermal efficiency. Recent studies on micro-scale combustion systems have also reported that thermal management and combustor structural configuration significantly influence heat transfer characteristics and flame stability in compact combustion devices [26]. These findings underline the importance of thickness as a key design parameter in achieving a stable and efficient combustion regime.

Accordingly, the present study systematically evaluates the effect of flame holder thickness (1.0–2.0 mm) on flame stability and heat transfer in a butane-fueled duralumin meso-scale combustor. Unlike previous works that primarily focused on material type or overall geometry [11-15], this study quantifies the correlation between geometric thickness and performance metrics, including flammability range ($\Delta\Phi \approx 0.3$) and total heat release ($\Delta Q \approx 1.99$ W). The quantitative evidence linking thickness variation to both thermal efficiency and stability has not been previously reported, filling a major gap in the understanding of meso-scale combustion design and providing a foundation for optimizing the balance between heat recirculation and quenching effects in miniaturized combustors. This work is among the first experimental investigations to systematically quantify the relationship between flame holder thickness, heat recirculation, and flame stability in a butane-fueled meso-scale combustor. The study introduces a new experimental framework that links geometric thickness variation to measurable parameters of flammability range and heat release, providing original insight into the thermal feedback mechanisms governing stable meso-scale combustion.

2. METHODOLOGY

The experimental combustor (Figure 1) included a quartz tube (inner diameter of 3.5 mm and wall thickness of 1 mm), a perforated duralumin flame holder, a recirculation tube, and a fuel-air injection system.

Figure 2 illustrates the specific temperature measurement points within the mesoscale combustor. The thermocouple positions are designated as T1, T2, T3, and T4 to monitor the thermal distribution along the combustion chamber during the experimental process.

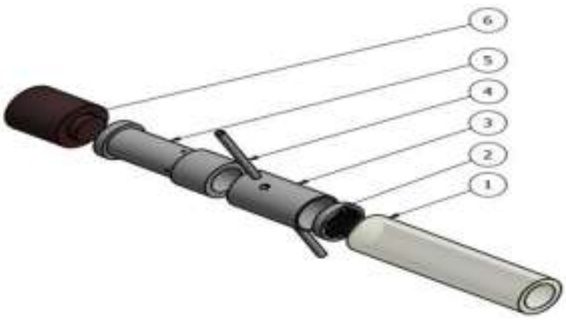


Figure 1. Mesoscale combustor: (1) Quartz glass tube; (2) Flame holder; (3) Recirculation tube; (4) Syringe needle; (5) Recirculator; (6) Ceramic

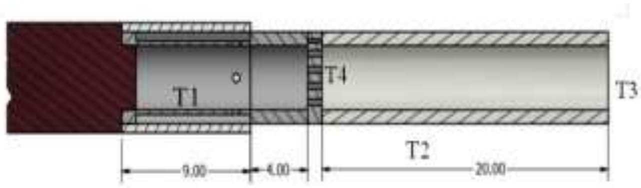


Figure 2. Temperature points in the mesoscale combustor

Flame holders (Figure 3) were fabricated from duralumin with an outer diameter of 5 mm and eight perforation lines (0.8 mm each). Thicknesses of 1 mm, 1.5 mm, and 2 mm were selected to ensure structural integrity under thermal loading.

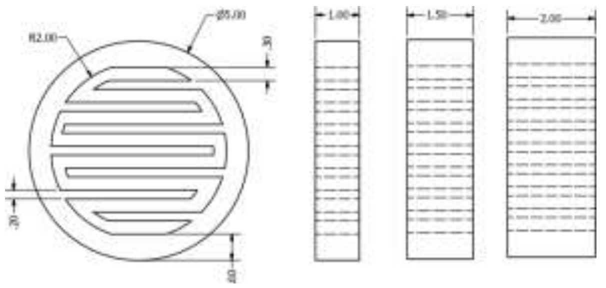


Figure 3. Duralumin flame holder in mm

The setup (Figure 3) used commercial butane (> 99% purity) supplied through a precision flowmeter (± 1.5% F.S.) and compressed air as oxidizer. The equivalence ratio (Φ) was adjusted between 1.0 and 1.9.

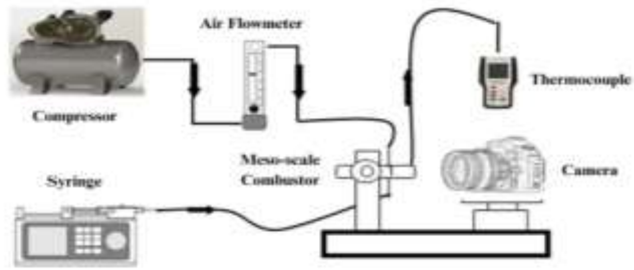


Figure 4. Experimental setup schematic

Figure 4 shows the experimental setup schematic. The flame behavior was recorded using a DSLR camera at 60 fps. The temperatures were measured using K-type thermocouples calibrated to a platinum resistance thermometer (± 0.2 ℃). Meanwhile, the flammability limits were identified by gradually varying velocity at fixed Φ until blow-off or flashback occurred.

2.1 Heat transfer calculations

The Nusselt number was used to estimate convective transfer:

$$Nu = \frac{hL}{k} \tag{1}$$

While h refers to convective heat transfer coefficient, L refers to characteristic length, and k refers to thermal conductivity.

The rate of convective heat transfer ($Qconv$) was calculated using:

$$Qconv = hA(Ts - T\infty) \quad (2)$$

While A refers to the flame holder surface area, Ts refers to the flame holder surface temperature, and $T\infty$ refers to the free-stream reactant temperature. Measurement uncertainty was estimated at ± 4.2%.

3. RESULTS

3.1 Flammability limits

Figure 5 presents the relationship between equivalence ratio (Φ) and reactant velocity for the 2 mm thick flame holder. The horizontal axis represents Φ, where Φ = 1 denotes a stoichiometric mixture, Φ < 1 represents fuel-lean conditions, and Φ > 1 represents fuel-rich conditions. The vertical axis shows the reactant velocity at which flame propagation occurs. The two boundary curves define the lower and upper flammability limits. Combustion remains stable only within the enclosed region, indicating that mixtures outside this range either fail to ignite or result in flame extinction.

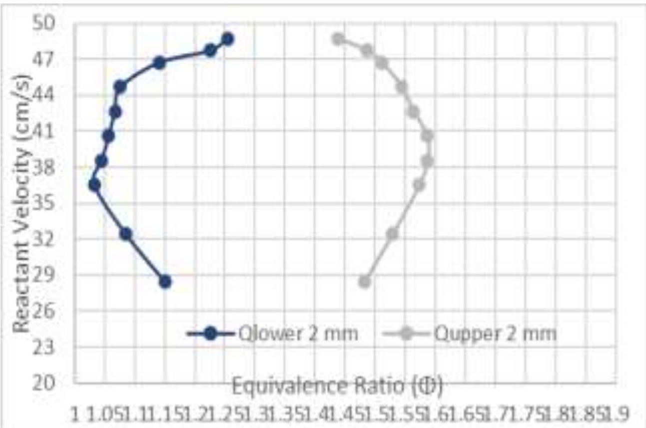


Figure 5. Graph of the relationship between equivalence ratio and mixture flow rate at 2 mm thickness

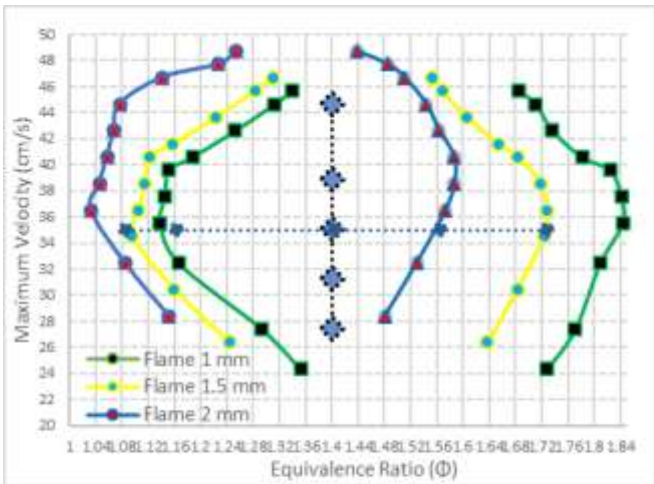


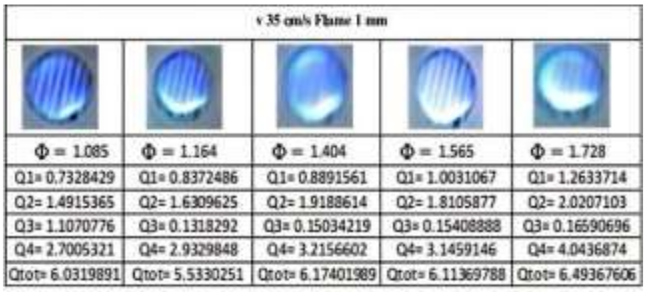
Figure 6. Graph of the relationship between equivalence ratio and mixture flow rate

Figure 6 compares the flammability limits for the three flame holder thicknesses. The 1 mm flame holder provides the widest stable flame range (Φ = 1.13–1.84), while the thicker flame holders shift the stable zone toward leaner mixtures and reduce its width. This trend suggests that increasing thickness changes the thermal environment, leading to narrower stability regions. The 2 mm flame holder shows the poorest stability, indicating higher susceptibility to blow-off and quenching.

The lowest flammability limit was recorded at Φ = 1.13 with a maximum velocity of 19.26 cm/s, below a point at which a flashback may occur. Meanwhile, the upper limit occurred at Φ = 1.84 with a velocity of 45.68 cm/s, beyond a point where blow-off may occur. The 1 mm flame holder's broader stability range results from improved heat recirculation and reduced quenching

3.2 Flame visualization

Figure 7 shows flame images at v = 35 cm/s for the 1 mm flame holder. As Φ increases from 1.085 to 1.728, flames become wider and more luminous, indicating higher combustion intensity and greater heat release (Qtot increases from 6.032 W to 6.494 W).



v 35 cm/s Flame 1 mm				
Φ = 1.085	Φ = 1.164	Φ = 1.404	Φ = 1.565	Φ = 1.728
Q1= 0.7328429	Q1= 0.8372486	Q1= 0.8891561	Q1= 1.0031067	Q1= 1.2633714
Q2= 1.4915365	Q2= 1.6309625	Q2= 1.9188614	Q2= 1.8105877	Q2= 2.0207103
Q3= 1.1070776	Q3= 0.1318292	Q3= 0.15034219	Q3= 0.15408888	Q3= 0.16590696
Q4= 2.7005321	Q4= 2.9329848	Q4= 3.2156602	Q4= 3.1459146	Q4= 4.0436874
Qtot= 6.0319891	Qtot= 5.5330251	Qtot= 6.17401989	Qtot= 6.11369788	Qtot= 6.49367606

Figure 7. Flame visualization at an inlet velocity of 35 cm/s for a 1 mm flame holder under varying equivalence ratios (Φ = 1.085–1.728)

v 35 cm/s Flame 1.5 mm				
Φ = 1.085	Φ = 1.164	Φ = 1.404	Φ = 1.565	Φ = 1.728
Q1 = 0.6854863	Q1 = 0.7887757	Q1 = 0.8394701	Q1 = 0.9530344	Q1= 1.2110673
Q2= 1.3842874	Q2= 1.5203696	Q2= 1.8064466	Q2= 1.6994548	Q2= 1.907136
Q3= 0.0989704	Q3= 0.12342712	Q3= 0.14145349	Q3= 0.14509538	Q3= 0.15106529
Q4= 2.5840558	Q4= 2.8135121	Q4= 3.0927261	Q4= 2.7552863	Q4= 2.7241353
Qtot= 4.7527999	Qtot= 5.24608452	Qtot= 5.88009629	Qtot= 5.55287088	Qtot= 5.99340389

Figure 8. Flame visualization at an inlet velocity of 35 cm/s for a 1.5 mm flame holder under varying equivalence ratios (Φ = 1.085–1.728)

v 35 cm/s Flame 2 mm				
Φ = 1.085	Φ = 1.164	Φ = 1.404	Φ = 1.565	Φ = 1.728
Q1 = 0.640074	Q1 = 0.742245	Q1 = 0.792427	Q1= 0.904912	Q1= 1.0229723
Q2= 1.257805	Q2= 1.3934917	Q2= 1.3934917	Q2= 1.5606147	Q2= 1.7536436
Q3= 0.105968	Q3= 0.1099307	Q3= 0.1178251	Q3= 0.1314072	Q3= 0.1371333
Q4= 2.496937	Q4= 2.7266234	Q4= 3.003225	Q4= 2.6689514	Q4= 2.638098
Qtot= 4.500785	Qtot= 4.9722912	Qtot= 5.5536432	Qtot= 5.2658853	Qtot= 5.5518472

Figure 9. Flame visualization at an inlet velocity of 35 cm/s for a 2 mm flame holder under varying equivalence ratios (Φ = 1.085–1.728)

Figure 8 displays the flame in the 1.5 mm flame holder. Although the flame still widens with increasing Φ, luminosity is noticeably reduced, indicating greater heat absorption by the thicker metal. The Qtot ranges from 4.753 W to 5.994 W, consistently lower than the 1 mm flame holder.

Figure 9 illustrates the flame in the 2 mm flame holder, which is dimmer and narrower. The values (4.501 W to 5.552 W) are the lowest among all configurations, reflecting reduced combustion efficiency due to higher heat absorption and greater cooling.

3.3 Temperature profiles

Figures 10 to 12 show the temperature profiles for each thickness at v = 35 cm/s. The 1 mm flame holder achieves the highest peak temperature (T_1 = 631.2°C, Q ≈ 0.889 W), while the 2 mm flame holder records the lowest (T_1 = 598.4°C, Q ≈ 0.792 W).

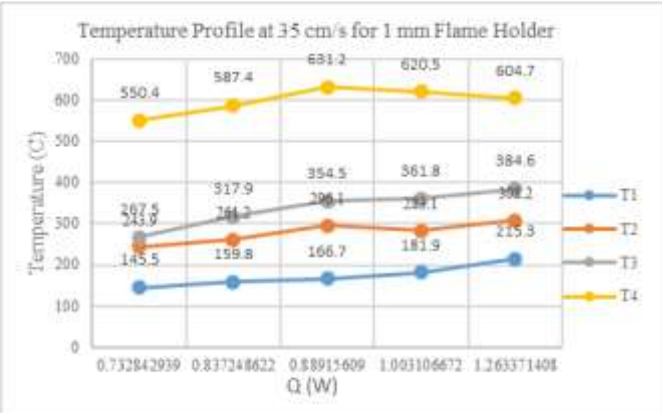


Figure 10. Temperature profile at 35 cm/s with a 1 mm thick flame holder

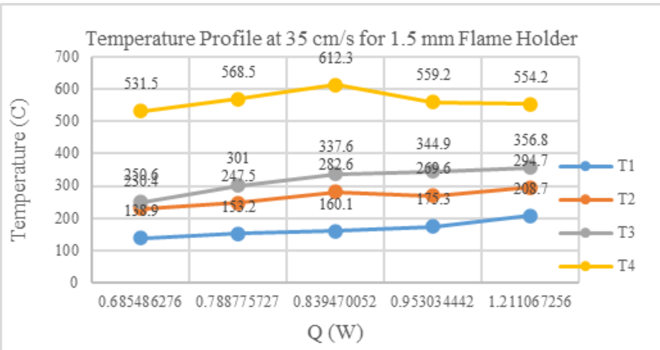


Figure 11. Temperature profile at 35 cm/s with a 1.5 mm thick flame holder

Temperature measurements at T_3 and T_4 further confirm the influence of thickness. The 1 mm flame holder maintains higher downstream temperatures due to reduced conductive losses, while thicker flame holders dissipate more heat to the structure, lowering gas temperatures and combustion efficiency.

These experimental results not only demonstrate the thermal and stability response of the flame with varying holder thickness but also offer important insight into combustor design optimization. The findings indicate that a thinner flame holder (around 1.0 mm) promotes more effective heat recirculation, minimizes local quenching, and stabilizes the flame front within the meso-scale channel. From a design perspective, this means that selecting a flame holder with controlled thin geometry can significantly improve combustion efficiency and operational reliability, particularly for compact or portable combustion systems where energy retention and stable operation are essential.

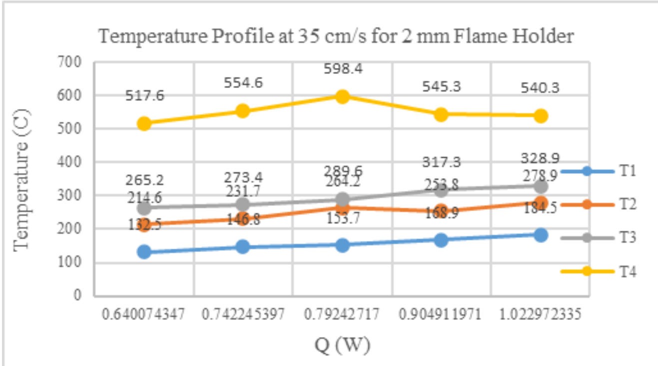


Figure 12. Temperature profile at 35 cm/s with a 2 mm thick flame holder

The position of temperature measurement also plays a crucial role in understanding the heat distribution. T_4, located near the flame holder, is highly influenced by the flame holder's thickness; the thinner the flame holder, the higher the T_4 temperature due to reduced heat absorption by the metal. T_3 and T_2, positioned further downstream along the combustion channel, exhibit temperature values that depend on how much heat is retained within the combustion gases. Thicker flame holders tend to dissipate more heat, leading to lower T_3 and T_2 readings. Meanwhile, T_1, located upstream and outside the flame holder area, is more affected by external conditions and the incoming fuel flow. These spatial variations in temperature highlight how heat transfer pathways strongly control flame–flow interactions, providing the basis for explaining the observed trends in flame stability and thermal efficiency.

As shown in Figures 6 to 12, the 1 mm flame holder consistently produced the widest flammability range (Φ = 1.13–1.84), highest peak temperature (631.2 °C), and greatest heat release (Qtot ≈ 6.494 W). These improvements can enhance heat recirculation from the flame to the incoming reactants, increasing preheating and promoting stable combustion.

The enhanced flame stability observed at a flame holder thickness of 1.0 mm correlates with a balanced thermal feedback mechanism between the combustor wall and the reacting flow. A thinner holder allows more effective heat recirculation from the downstream hot zone to the incoming reactant mixture, sustaining the local temperature above the ignition threshold and preventing flame extinction. In contrast, increasing the holder thickness intensifies heat conduction into the metal, leading to greater thermal losses and localized quenching near the wall surface.

This phenomenon can be further interpreted through the combined effects of conduction, convection, and thermal diffusivity ($\alpha = k/\rho c_p$). Duralumin, the flame holder material, has a relatively high thermal diffusivity (~5 × 10^{-5} m^2/s), allowing heat absorbed at the flame surface to rapidly propagate through the metal. When the holder thickness increases, conductive heat transfer through the wall dominates, causing a larger portion of the thermal energy to be dissipated internally rather than recirculated to the flame zone. At the same time, the enlarged surface area enhances convective heat losses to the surrounding flow, particularly in areas exposed to cooler incoming reactants. These combined conductive and convective losses reduce the local flame temperature and weaken the heat feedback required for a stable combustion.

Conversely, the thinner 1.0 mm configuration limits both internal conduction and surface convection while retaining sufficient heat for feedback, maintaining the temperature near the ignition limit, and enabling a stable flame front. This explanation is consistent with the findings of Liu et al. [24] and Peng et al. [25], who reported that excessive wall thickness reduces effective thermal feedback and destabilizes meso-scale combustion. Hence, the 1.0 mm flame holder achieves the optimal compromise between structural integrity, conductive heat transport, and convective dissipation, resulting in superior stability and thermal performance.

3.4 Heat transfer interpretation

From a heat transfer perspective, thinner flame holders increase the convective heat transfer coefficient (h) by reducing conductive heat absorption into the metal body, thus retaining more thermal energy in the gas phase. This effect reduces the local quenching tendency, as the flame temperature remains above the quenching temperature threshold for butane-air mixtures (560–580℃). Conversely, thicker holders (2 mm) perform as stronger heat sinks, reducing (Ts - $T\infty$) and narrowing the stability window due to premature flame extinction at lean and rich limits.

The trends observed in this study are consistent with the work of Wan and Zhao [13], who reported that excessive metallic mass in micro-combustors can reduce blow-off velocity by up to 25% due to quenching. However, the present results extend this understanding by quantitatively linking thickness variation (Δ = 1.0 – 2.0 mm) with measurable changes in flammability limit width ($\Delta\Phi$ up to 0.3) and heat release rate (ΔQ up to 1.99 W). These parameters were rarely reported concurrently in the prior mesoscale combustion studies.

The present findings conform to the observations of Wan and Zhao [13], who reported that a thinner wall structure enhances the stability of meso-scale flames by promoting stronger heat recirculation and reducing local quenching. In both studies, the flame remains anchored near the holder edge when the thickness is minimized, confirming that the geometric constraint directly affects the local energy balance. However, while Wan et al. [18] focused primarily on material and general wall geometry, the current work extends the findings by quantifying the specific role of flame holder thickness (1.0–2.0 mm) and its direct effect on the flame stability limit and the overall heat transfer rate. The quantitative correlation between thickness and temperature distribution in this work provides additional experimental validation for the theoretical trends proposed by Wan and Zhao [13], reinforcing the critical role of geometric scaling in meso-scale combustor design.

Quantitatively, the experimental data show that reducing the flame holder thickness from 2.0 mm to 1.0 mm increases the peak temperature near the flame front (T4) by approximately 12 to 15% and improves the overall thermal efficiency by nearly 10%. Correspondingly, the flammability range expands by about 0.3 ϕ, indicating a broader area of stable operation. These results demonstrate that geometric thickness exerts a strong effect on the heat transfer characteristics. The thinner holders enhance heat feedback and sustain combustion stability. From a design perspective, a 1.0 mm flame holder provides the optimal compromise between structural strength and thermal performance, serving as a practical guideline for fabricating small-scale or portable combustors. Thus, the quantified relationship between thickness variation and performance metrics forms an empirical foundation for future optimization in mesoscale energy devices.

Moreover, the broader stability envelope obtained with the 1 mm configuration is particularly relevant for portable power systems when operating conditions are highly variable. Maintaining a wide Φ range ensures better tolerance to transient changes in fuel-air mixing quality. This finding suggests that optimizing flame holder geometry must balance structural integrity with thermal mass minimization, a design trade-off that is underexplored in the literature.

4. CONCLUSIONS

This study investigated the influence of flame holder thickness on the thermal performance, flammability limits, and flame stability of a meso-scale combustor. The duralumin flame holders with thicknesses of 1 mm, 1.5 mm, and 2 mm were tested under controlled conditions using butane fuel.

The results demonstrate that flame holder thickness significantly affects temperature distribution, heat transfer, and combustion stability. The 1 mm thick flame holder provided the broadest flammability range (Φ = 1.13–1.84), higher peak temperatures, and a greater heat release compared to thicker configurations. This improvement correlates with enhanced heat recirculation and reduced conductive losses, which increase reactant preheating and extend flame stability.

Moreover, the experimental findings directly impact the practical design. The quantitative relationship between flame holder thickness and thermal performance offers a design parameter that is directly applicable to the fabrication of compact combustors. Selecting a thickness near 1.0 mm provides an optimal balance between heat retention and mechanical strength, which can be utilized in the development of portable power generation systems, micro-heating units, and miniature propulsion devices. Furthermore, the temperature and stability data obtained in this study can serve as reference values to validate numerical simulations or guide optimization models aimed at improving fuel efficiency and stability in meso-scale energy applications.

However, this study is limited to a single fuel type (butane) and a specific flame holder material (duralumin), which may influence the observed heat transfer and flame stability characteristics. Butane has a relatively low latent heat of vaporization and high heating value, enabling easy vaporization and stable ignition. Meanwhile, duralumin's high thermal conductivity (approximately 120 to 150 W/m·K) promotes conductive heat losses along the holder surface. Therefore, the results represent a particular configuration rather than a universal behavior across all fuels or materials. Additionally, the experiments were conducted under steady inlet flow conditions without any evaluation of transient or turbulent effects that may occur in real applications. Future work should extend the present findings by exploring different fuel types, such as hydrogen or propane, and alternative materials with varying thermal conductivities. Investigating multi-port or curved geometries could also provide a deeper understanding of how structural scaling interacts with combustion stability in meso-scale systems.

Despite these experimental limitations, the present study establishes a novel experimental framework that quantitatively links the flame holder thickness, thermal behavior, and flame stability. The results fill a critical gap in meso-scale combustion research and offer a solid foundation for future optimization, modeling, and design of compact and efficient combustion systems.

ACKNOWLEDGMENT

This research was funded by an internal research grant from Universitas Muhammadiyah Malang and conducted in collaboration with Prof. Tim Pasang from the Engineering Design, Manufacturing, and Management Systems Department at Western Michigan University, USA.

REFERENCES

[1] Wang, M.H., Li, P.F., Wang, F.F. (2020). Dependence of the blowout limit on flow structure, heat transfer, and pressure loss in a bluff-body micro-combustor International Journal of Hydrogen Energy, 45(38): 19912-19925. https://doi.org/10.1016/j.ijhydene.2020.04.113

[2] Qian, P., Yuan, X.P., Chen, Z.W., Luo, C.Y., Huang, Z.Z., Zhu, X.G., Liu, M.H. (2021). Experimental study on a high efficient and ultra-lean burn meso-scale thermoelectric system based on porous media combustion. Energy Conversion and Management, 234: 113966. https://doi.org/10.1016/j.enconman.2021.113966

[3] Chen, X.J., Li, J.W., Feng, M., Zhao, D., Shi, B.L., Wang, N.F. (2019). Flame stability and combustion characteristics of liquid fuel in a meso-scale burner with porous media. Fuel, 251: 249-259. https://doi.org/10.1016/j.fuel.2019.04.011

[4] Goodarzi, F., Kondori, J., Rezaei, N., Zendehboudi, S. (2019). Meso- and molecular-scale modeling to provide new insights into interfacial and structural properties of hydrocarbon/water/surfactant systems. Journal of Molecular Liquids, 295: 111357. https://doi.org/10.1016/j.molliq.2019.111357

[5] Wan, J.L., Fan, A.W. (2021). Recent progress in flame stabilization technologies for combustion-based micro energy and power systems. Fuel, 286: 119391. https://doi.org/10.1016/j.fuel.2020.119391

[6] Choi, J., Rajasegar, R., Mitsingas, C.M., Liu, Q., Lee, T., Yoo, J. (2020). Effect of flame interaction on swirl-stabilized mesoscale burner array performance. Energy, 192: 116661. https://doi.org/10.1016/j.energy.2019.116661

[7] Yang, X., Yu, B., Yang, W.M., Zhou, H.C. (2021). Investigation of heat transfer characteristics of hydrogen combustion process in cylindrical combustors from microscale to mesoscale. International Journal of Hydrogen Energy, 46(51): 25893-25907. https://doi.org/10.1016/j.ijhydene.2021.05.099

[8] Chen, J.J., Pang, Z.W. (2021). Catalytically stabilized combustion characteristics of methane-air mixtures in micro-scale heat-recirculating systems. Fuel, 306: 121693. https://doi.org/10.1016/j.fuel.2021.121693

[9] Banerjee, A., Paul, D. (2021). Developments and applications of porous medium combustion: A recent review. Energy, 221: 119868. https://doi.org/10.1016/j.energy.2021.119868

[10] Zuo, W., E, J.Q., Lin, R.M., Jin, Y., Han, D.D. (2018). Numerical investigations on different configurations of a four-channel meso-scale planar combustor fueled by hydrogen/air mixture. Energy Conversion and Management, 160: 1-13. https://doi.org/10.1016/j.enconman.2018.01.033

[11] Zhao, S., Wei, R. (2023). Mixed combustion characteristics of various biomass particles. Journal of Sustainability for Energy, 2(1): 19-28. https://doi.org/10.56578/jse020102

[12] Rezaei, R.A., Khezerloo, M. (2023). Enhancement of thermal efficiency in gas-fired heaters through a novel double-walled chimney design. Journal of Sustainability for Energy, 2(3): 109-118. https://doi.org/10.56578/jse020301

[13] Wan, J.L., Zhao, H.B. (2020). Blow-off mechanism of a holder-stabilized laminar premixed flame in a preheated mesoscale combustor. Combustion and Flame, 220: 358-367. https://doi.org/10.1016/j.combustflame.2020.07.012

[14] Ma, L., Xu, H., Wang, X.T., Fang, Q.Y., Zhang, C., Chen, G. (2019). A novel flame-anchorage micro-combustor: Effects of flame holder shape and height on premixed CH4/air flame blow-off limit. Applied Thermal Engineering, 158: 113836. https://doi.org/10.1016/j.applthermaleng.2019.113836

[15] Li, Y.H., Peng, K.H., Kao, H.H. (2021). Interaction between flow structure and chemical reaction around the perforated gap of stainless steel–platinum catalytic partition reactor. International Journal of Heat and Mass Transfer, 176: 121418. https://doi.org/10.1016/j.ijheatmasstransfer.2021.121418

[16] Rahbari, A., Homayoonfar, S., Valizadeh, E., Aligoodarz, M.R., Toghraie, D. (2021). Effects of micro-combustor geometry and size on the heat transfer and combustion characteristics of premixed hydrogen/air flames. Energy, 215: 119061. https://doi.org/10.1016/j.energy.2020.119061

[17] Zhao, S.L., Fan, Y.X. (2020). Experimental and numerical study on the flame characteristics and cooling effectiveness of air-cooled flame holder. Energy, 209: 118421. https://doi.org/10.1016/j.energy.2020.118421

[18] Wan, J.L., Xu, Z.W., Zhao, H.B. (2018). Methane/air premixed flame topology structure in a mesoscale combustor with a plate flame holder and preheating channels. Energy, 165: 802-811. https://doi.org/10.1016/j.energy.2018.09.172

[19] Miao, J.J., Fan, Y.X., Wu, W.Q., Zhao, S.L. (2021). Effect of air-assistant on ignition and flame-holding characteristics in a cavity-strut based combustor. Applied Energy, 283: 116307. https://doi.org/10.1016/j.apenergy.2020.116307

[20] Wang, Y.H., Song, W.Y. (2019). Experimental investigation of influence factors on flame holding in a supersonic combustor. Aerospace Science and Technology, 85: 180-186. https://doi.org/10.1016/j.ast.2018.12.002

[21] Soegiharto, A.F.H., Munir, F.A., Aisyah, I.S., Aryanamurti, M.P., Yuliati, L., Ayun, E.L.F. (2023).

Characteristics of butane combustion in mesoscale–combustor due to stainless steel flame holder type. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 104(2): 161-173. https://doi.org/10.37934/arfmts.104.2.161173

[22] Sudarman, Soegiharto, A.F.H., Suyanto, A., Mamungkas, M.I., Ayuni, E.L.F. (2023). The influence of heat recirculation segment of meso-scale combustor on gas and liquid fuel inside microscale combustor. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 104(1): 141-151. https://doi.org/10.37934/arfmts.104.1.141151

[23] Ata, A., Özdemir, I.B. (2021). Stability characteristics of a turbulent nonpremixed conical bluff body flame. International Journal of Heat and Technology, 39(3): 737-745. https://doi.org/10.18280/ijht.390307

[24] Liu, L., Zhao, L., Fan, A.W. (2019). Effects of wall thickness and material on flame stability in a planar micro-combustor. Journal of Central South University, 26: 2224-2233. https://doi.org/10.1007/s11771-019-4168-6

[25] Peng, Q.G., E, J.Q., Chen, J.W., Zuo, W., Zhao, X.H., Zhang, Z.Q. (2018). Investigation on the effects of wall thickness and porous media on the thermal performance of a non-premixed hydrogen fueled cylindrical micro combustor. Energy Conversion and Management, 155: 276-286. https://doi.org/10.1016/j.enconman.2017.10.095

[26] Ayuni, E.L.F., Rahmandhika, A., Daryono, Lesmawanto, A., Rizkyawan, K.B., Mokhtar, A., Soegiharto, A.F.H. (2024). The effect of insulation thickness on heat transfer characteristics and flammability in tube mesoscale combustors. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 116(2): 157-171. https://doi.org/10.37934/arfmts.116.2.157171

NOMENCLATURE

Nu	Nusselt number
Q	heat release, W
h	convective heat transfer coefficient, W/m²·K
L	characteristic length, m
k	thermal conductivity, W/m·K
A	flame holder surface area, m²
U	flow velocity, cm/s
T	temperature, °C

Greek symbols

ϕ	equivalence ratio