American Journal of Smart Technology and Solutions (AJSTS)

ISSN: 2837-0295 (ONLINE)

VOLUME 4 ISSUE 1 (2025)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Smart Technology and Solutions (AJSTS)

Volume 4 Issue 1, Year 2025
ISSN: 2837-0295 (Online)
DOI: https://doi.org/10.54536/ajsts.v4i1.4614
https://journals.e-palli.com/home/index.php/ajsts

Simulation and Performance Enhancement of Thermal Combustion in a Liquid Fuel Swirl Burner Through Blades Parametric Variation

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Article Information

Received: February 22, 2025

Accepted: March 28, 2025

Published: June 20, 2025

Keywords

Combustion, Pressure Drop, Simulation, Swirl Burner, Temperature

ABSTRACT

Research has explored the need for an increase in the performance of a Liquid Fuel Swirl Burner (LFSB). An experimental study carried out in LFSB having a varied number of blades and angles of blades yielded the desired improvement. To further improve on the experimental work, extended study is required. This was carried out through Computational Fluid Dynamics Simulation methods, which is cost-effective and have been established to be reliable. This study therefore explores the comparison between experimental results and simulation means to validate the simulation methods and results obtained. The work aimed to enhance thermal combustion in the swirl burner through variations in the blade angles (10°, 20°, 30°, 40°, 45°, 50°, 60°, 70°) and the number of blades in the burner (4, 6, 8, 10 and 12). Computational methods were employed when designing and simulating the burner's parameters using SolidWorks and ANSYS Fluent. The result showed that the burner with 10 blades at 70° yielded the highest temperature of 1024.547°C and the burner with 12 blades at 10° degrees produced the lowest pressure drop of 11973219.93Pa. Thereby improved combustion was achieved by obtaining the highest temperature at the burner outlet and lowest pressure drop which yielded effective combustion.

INTRODUCTION

The process of combustion describes the transformation of chemical energy (from the fuel substance utilized) to other types of energy including, thermal, electrical, gravitational, kinetic, nuclear and electromagnetic. The well-known definition of energy is that it is the ability to do work, in this article by Clark & Yusoff (2014), combustion is regarded as a variation of work where the atomic bonds of a substance (fuel) are liberated through oxidation reaction and as a result, the products are the generation of heat and the creation of new chemical bonds. The world accounts for 80% of its energy generation through the use of fossil fuels (crude oil, natural gas and coal) (Aliyu *et al*., 2015) The primary mode of utilizing fossil fuels for the generation of electricity is through combustion (Martins & Brito, 2020). Alternative energy, sustainable energy and clean energy are arguably interchangeable terms used to describe Renewable energy. Renewable Energy is energy that is derived from replenish able means. It is used to produce continuous energy (Panwar *et al*., 2011). Nations that are still undergoing development are at risk to climate change more so than already developed nations (Ikein, 2017). This is as a result of their economies prevalence on agriculture, the lack of capital to properly adjust to these changes in their climate and their increased exposure to the effects. Unlike developed nations such as the United States of America, Russia, Germany etc, that have the capabilities in producing and manufacturing needed to successfully switch to Renewable Energy Technologies, such as wind turbines, hydrogen fuel cells and photovoltaic cells (Ogbonnaya *et al*., 2019). Examples of combustion fuels are carbon dioxide (CO_2), perfluorocarbons, sulphur hexafluoride, nitrogen trifluoride, nitrous oxide, hydrofluorocarbons, and methane (European Parliament, 2023). Over the years, researchers have found many ways to improve combustion. Among these technologies is the introduction of swirling flows to the design of a burner. According to (Sengupta *et al*., 2021), the smooth and undisturbed operation of a burner is subject to stringent conditions during its design. According to Mansouri and Boushaki (2018) in recent times, the design of burners includes vanes which are used in aerodynamically stabilizing the flames. These vanes are referred to as swirlers. With the introduction of these swirlers to the design of a burner, the burner is known as a swirl burner. A swirl burner is a burner of helical configuration that produces swirling flows during combustion (Boushaki, 2019). The Swirl Burner utilizes guiding vanes whose purpose is to supply the swirl flow to air for combustion (Xiao *et al*., 2018). Utilization of non-premixed swirl in the process of combustion has a number of advantages including the ability to control the flow coupled with the abatement of harmful pollution emission primarily in the form of NOx (nitrogen oxides) (Schmittel *et al*., 2000). In a study by Sreenivasan *et al*. (2012), it is noted that premixed flames generate less of hazardous gases such as carbon monoxide and soot. The advantages of using swirl burners are numerous. In Day *et al*. (2003), the classification of swirl burners was noted as follows: Swirl burners are classified into axial vane burners, tangential vane burners, and volute burners. The major types of swirlers were also noted namely: volute swirler, tangential vane swirler, axial vane swirler. In the research by Yang *et al*. (2019), premixed and non-premixed combustion modes were both explored in a swirling micro-combustor

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that can be fuelled by hydrogen or air. Their effects on the efficiency of combustion, thermal performance and flame stability were explored.

In their research, Oyewola, *et al.* (2022) explored the thermal profile of combustion in experimental means in a Liquid Fuel Swirl Burner and this approach was done through alternatively changing the configuration of the blades at angles 20°, 30°, 40°, 50°, 60°. The blades were also assembled in the order of 6, 8, 10 and 12. The primary purpose of their research was to increase the temperature of the burner thereby enhancing combustion dynamics. For the straight-edge blades, the highest thermal efficiency recorded was achieved using 6 blades inclined at an angle of 50° (Oyewola *et al.* 2022). Jaafar *et al.* (2012) examined in their research that the determination of the swirl number is an important characteristic in the design of a swirl burner as it assists in ensuring the correct order of the swirl blades. It was also noted in their research that the decrease of the depth of the swirl blade without a modification to the swirl blade angle will lead to an improvement in the swirl strength. To further emphasize the importance of swirl blades in the optimization of combustion in a burner, (Surjosatyo & Priambodho, 2011) reported that to enhance the quality of the flame or the strength of the flame in a low-swirl burner, swirl vanes of 6, 8 and 10 in number, inclined at an angle of 30 from the horizontal axis are needed to decrease the diameter of the fuel entering at the inlet side of the burner. In research by (Dhyani & Phade, 2024), Computer-Aided Design (CAD) techniques using SolidWorks 2022 was utilized in designing a burner and its vanes. Benim *et al.*, (2022) performed research utilizing a mixture of pulverized coal with biomass in an oxy-combustion process in a swirl burner using computational means. Not enough research extensively focuses on the modification of the blades of the swirl. This modification could be achieved through several ways, perforations in the blades could be a means and as done by (Akinwonmi *et al.*, 2023) in the research, six swirl blades were presented with the modification of the angles and blade type (straight and curved edge blades) and also the variation of the angles of the blades ultimately yielding a positive result. Most engineering systems usually require a combustion system. Configuration of the burner itself will have an impact on the combustion efficiency and emission of the burner. High cost of experimentation limits the optimization of burner parameters for efficient performance of burners and other combustion systems. These are several studies on the use of simulation packages such as Ansys, Abacus, and MATLAB to optimize process parameters thereby reducing production cost and time. However, there are limited studies on the use of computational software in optimising process parameters and performance of Liquefied Fuel Swirl Burner (LFSB) therefore, the aim of this study is to evaluate the performance of an LFSB using computational fluid dynamics module in Ansys. The problem statement of this research paper aims to tackle, analyse and proffer a means of optimizing combustion in a swirl burner through the modification and redesign of its blades. This research is limited to the enhancement of combustion through the redesign of the blades. The main parameters considered in the blades include the shape and the angle in which they are configured on the swirl burners.

MATERIALS AND METHODS

Experimental study

The detailed results on the experimental set-up and the results gotten were obtained from Oyewola *et al.* (2022). Fuel supply (diesel) enters the atomizer at a pressure above 10 bar. While air proceeds through the output centrifugal blower with a 2" gate valve utilized for changing the air flow rate. The material used in the construction of the combustion chamber is stainless pipe steel 304 that has a thickness = 4mm, with dimension108 x 420mm per modular section. There are five modules in total. Each module has a flange machined with a projection that exactly fits the recess on the adjacent module, preventing leakage. The module at the base is fastened to the burner body by a 1 M10-6H bolt and nut. There are ports provided for measurement probes in each module. Observing and evaluating the flame length, velocity and pressure drop is done via the modular combustion chamber. The material used in making the blades and vanes is mild steel that is welded to the centre core on a rode whose base has been threaded to the burner for fastening/tightening utilizing the M10-GH nut. From the above data analysed from research carried out by Oyewola *et al.* (2022), it is important to note that the efficiency of the combustion was measured based on these four parameters: Flame length, Combustion Temperature, Velocity and Pressure Drop.

CFD Simulation

The physical geometry/model is drawn with SolidWorks software before being imported into Ansys Fluent for CFD simulation. CFD software (Ansys Fluent) is utilised to simulate combustion. The combustion performance parameters for this study are: the maximum temperature and the pressure drop. Meshing and grid sensitivity was done on the physical model, while governing equation such as the continuity equation, momentum and energy conversion equation were implemented to solve the thermal problems of combustion and airflow.

The flow type was determined using Reynolds number: $Re = (\rho v d)/\mu$

Where: ρ = ambient air density, v = velocity = 12m/s, d = diameter of the inlet of the combustion chamber, μ = viscosity (Taking the ambient air density as ρ = 1.2 kg/m and velocity v = 12m/s

The estimated value of Re is more than 3500, suggesting that the flow is turbulent. A turbulent model was selected. Assigning premixed flow, boundary conditions at the inlet, the wall and the outlet will be assigned as:

Inlet: Mass flow rate and initial temperature.

Outlet: Pressure Outlet

Wall: Adiabatic and non-slip conditions
The CFD analysis was validated by comparing the result with the experimental study. Once the temperature and pressure drop characteristics have been established, the geometry was varied to obtain an optimized design. The Assembled drawings were designed in the format of the table below making a total of 25 different drawings. The schematic of the burner geometry and the blades are shown in Figure 1 and Figure 2 respectively, while the configurations of the blades are shown in Table 1.

Table 1: No of Blades and Angles modelled.

	Angles							
No of Blades	10°	20°	30°	40°	45°	50°	60°	70°
4 blades	√	√	√	√	√	√	√	√
6 blades	√	√	√	√	√	√	√	√
8 blades	√	-	-	-	√	-	-	√
10 blades	√	-	-	-	√	-	-	√
12 blades	√	-	-	-	√	-	-	√

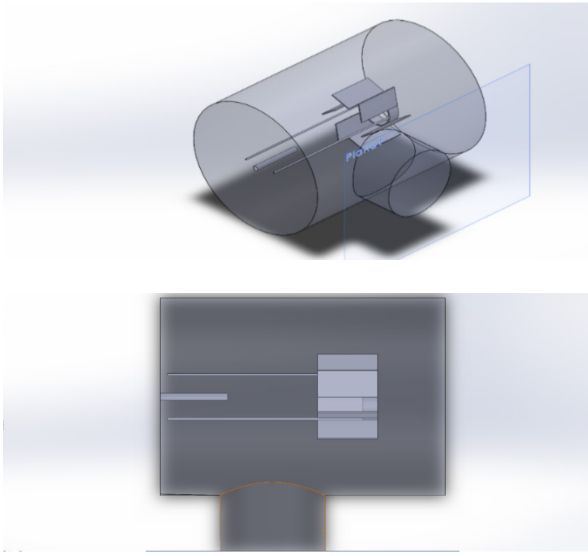


Figure 1: The burner geometry. (a) Isometric View (b) sectional view.

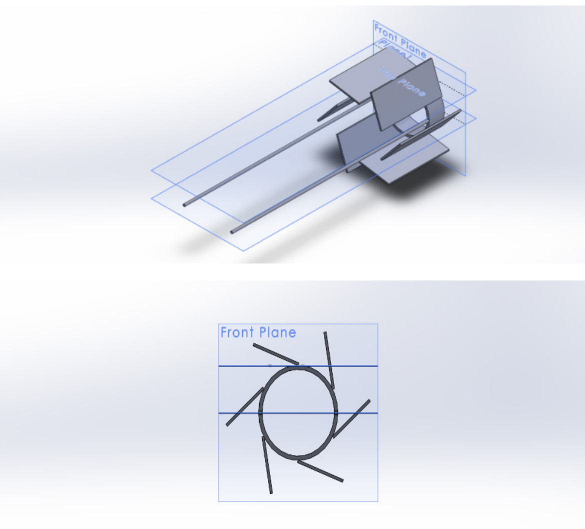


Figure 2: Blades design. (a) The Isometric View (b) front view

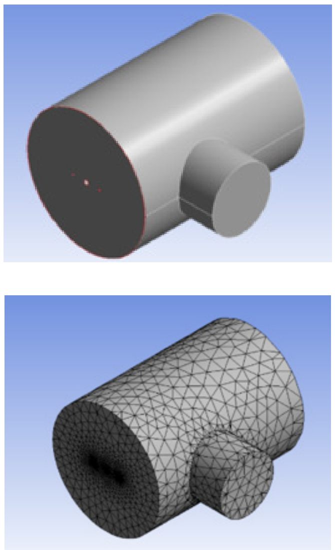


Figure 3: 3D geometry of swirl burner. (a) Unmeshed (b) meshe

RESULTS AND DISCUSSIONS

The Results of the Simulation done with ANSYS Fluent are discussed in this chapter. As mentioned in the methodology, the number of blades and angle type were varied to obtain the temperature at the outlet of the burner (combustion chamber) and the pressure drop at the outlet.

Temperature from Outlet of the Burners

Table 2 shows the varying temperatures obtained when the simulation was carried out through ANSYS Fluent and results were obtained. For the LFSB configuration with 4 and 6 blades, temperature results obtained cut across angles (10°, 20°, 30°, 40°, 45°, 50°, 60°and 70°) whilst for 8-blade, 10-blade and 12-blade LFSB configurations, the temperature results obtained were for (10°, 45°and 70°) only.

Table 2: Outlet temperature (°C) at different blade angles

	Blade Angles (°)	4 Blades	6 Blades	8 Blades	10 Blades	12 Blades
1.	10	697.167	656.202	687.11177	657.24116	666.6095
2.	20	700.329	709.767	-	-	-
3.	30	669.301	713.179	-	-	-
4.	40	672.824	660.198	-	-	-
5.	45	670.306	654.376	664.9423	654.02811	654.48336
6.	50	674.064	666.579	-	-	-
7.	60	666.677	657.335	-	-	-
8.	70	679.202	687.454	668.31346	1024.5465	667.36365

Validation of Simulation Result with Experimental Result

The Liquid Fuel Swirl Burner used in this comparison has 6 blades. The comparison study observes the variation in temperatures across angles 20°, 30°, 40°, 50° and 60°. The detailed study is expressed in Table 3 and Figure 4. There is a similarity in the trend of the graph of both the experimental and simulation results. There is an increase in the trend of the angles 30°to 40° and from 40° to 50° of the Experimental results and an increase in the trend of the 20°to 30° and from 40° to 50° of the simulation results. The experimental result has higher temperatures, and the contribution to this is that it is an exothermic reaction, and there is the influence of environmental factors on the result. The exemption of environmental factors and simulation procedure has contributed to the simulation results obtained.

Table 3: Variation of simulation result with experimental results for 6 number of blades

Blade Angle (°)	Experimental Results	Simulation Results	Percentage Difference (%)
20	812	709.76	12.59
30	857	713.18	16.78
40	885	660.20	25.40
50	941	666.58	29.16
60	918	657.34	28.39

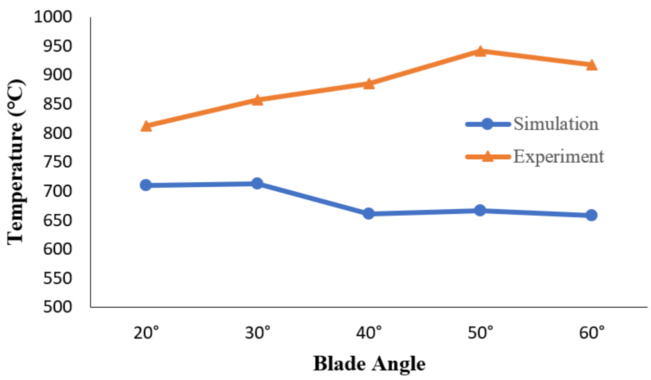
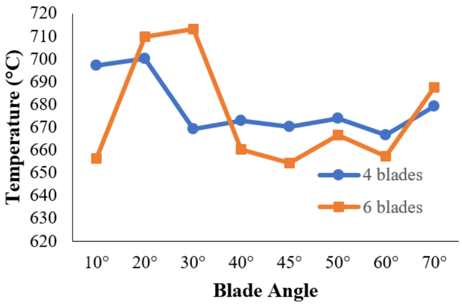


Figure 4: Comparison of experimental and simulation results for 6 number of blades

Effect of Blade Angle on Temperature Performance

Figure 5(a) shows the variation of the trends on the graph. According to the graph, the swirl burner with 6 blades produced the highest temperature at 30°. The LFSB with 6 blades at 45° produced the lowest temperature. Figure 2(b) shows the variation of the trends on the graph. According to the graph, the swirl burner with 6 blades produced the highest temperature at 70°. The LFSB with 6 blades at 45° produced the lowest temperature. Figure 2(c) a bar chat was used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the variation of blades with the highest temperature is 10 blades at 70°. The variation of blades that produce the lowest temperature is 10 blades at 45°.



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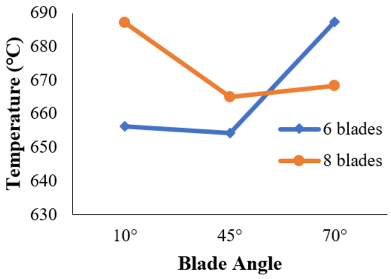

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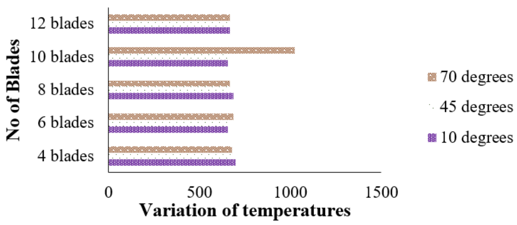
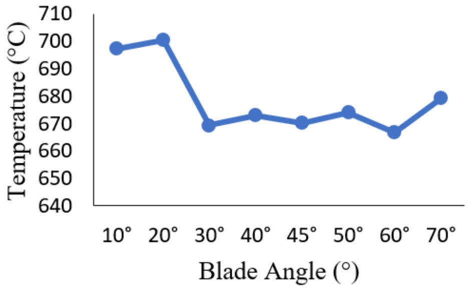


(c)

Figure 5: Effect of blade angles on output temperature (a) 4 and 6 blades (b) 6 and 8 blades (c) Effect of blade angles (10, 45 and 70 degrees) on output temperature.

Effect of Number of Blades on Temperature Performance

Figure 6(a) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest temperature produced for 4 blades is 20° and the lowest temperature is 60°. Figure 6(b) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest temperature produced for 6 blades is 30° and the lowest temperature is 45°. Figure 6(c) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest temperature produced for 8 blades is 10° and the lowest temperature is 45°. Figure 6(d) a line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest temperature produced for 10 blades is 70° and the lowest temperature is 45°. Figure 6(e) a line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest temperature produced for 12 blades is 70° and the lowest temperature is 45°.



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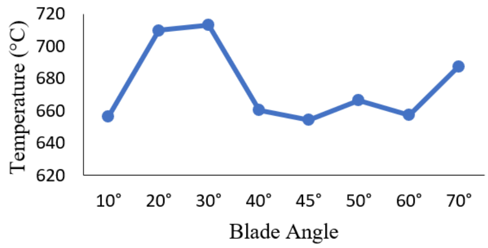

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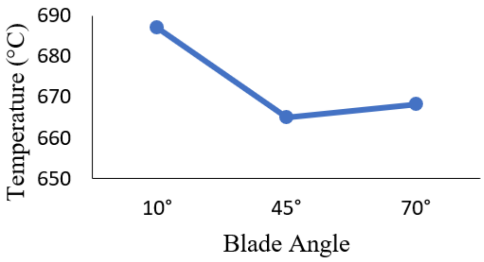

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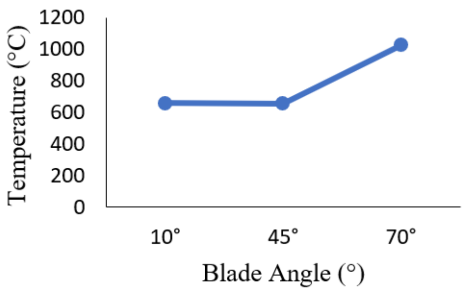

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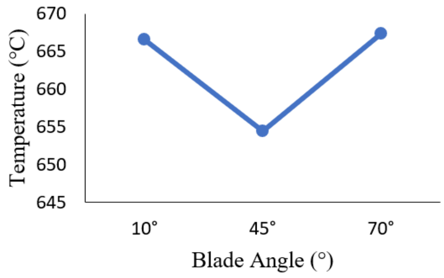


(e)

Figure 6: Effects of number of blades on temperature performance (a) 4 Blades (b) 6 Blades (c) 8 Blades (d) 10 Blades (e) 12 Blades

Pressure Drop from Outlet of The Burner

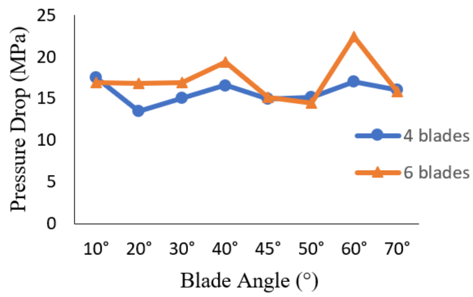
The pressure drops at different blade angles are presented in Table 4. The configuration with the least pressure drop is the most efficient. It can be observed that the pressure drop varied from 13.4 MPa to 17.4 MPa when 4 blades were used. The least pressure drop was recorded at an inclination of 20° while the most pressure drop was recorded at 10°. Increasing the number of blades to 6 showed that a maximum pressure drop of 22.4 MPa was recorded at 60° while a minimum of 14.5 MPa was recorded at 50°. For 8, 10, and 12 blades, only three angles were investigated. The angles are 10°, 45°, and 70°. In all, 45° recorded the least pressure drop. The pressure drop at 45° was similar regardless of the number of blades ranging between 14 – 15 MPa. This shows that 45° inclination would be a suitable configuration to obtain a reasonable pressure drop in the swirl burner. However, the best performing configuration is 4 blades at 20°.

Table 4: Pressure Drop (Pa) at different blade angles

Blade Angles (°)	4 Blades	6 Blades	8 Blades	10 Blades	12 Blades
10	17447983	16935336.8	19300927.7	18758026.2	11973219.9
20	13444413.6	16819360.7	-	-	-
30	15030043	16926780.5	-	-	-
40	16559992.4	19377894	-	-	-
45	14972311.8	15088128	15889589.4	13929679.1	14793106.5
50	15140152.7	14479914.8	-	-	-
60	16987400.4	22395036.1	-	-	-
70	16018733.3	15776540.5	18045876.7	20098840.9	18382667.4

Effect of Blade Angle on Pressure Drop Performance of Swirl Burners

Figure 7 (a) A line chart was used to show the variation of the trends on the graph. According to the graph, the swirl burner with 6 blades produced the highest temperature at 60°. The LFSB with 4 blades at 20° produced the lowest temperature. Figure 7 (b) A line chart was used to show the variation of the trends on the graph. According to the graph, the swirl burner with 8 blades at 10° produced the highest temperature. The LFSB with 6 blades at 45° produced the lowest temperature. Figure 7 (c) A line chart was used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the variation of blades with the highest temperature is 10 blades at 70°. The variation of blades that produce the lowest temperature is 12 blades at 10°.



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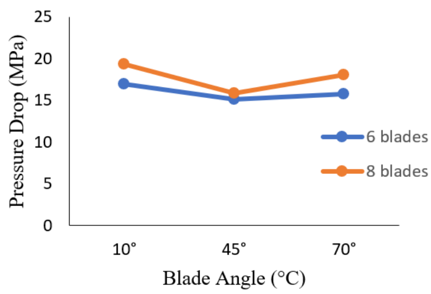

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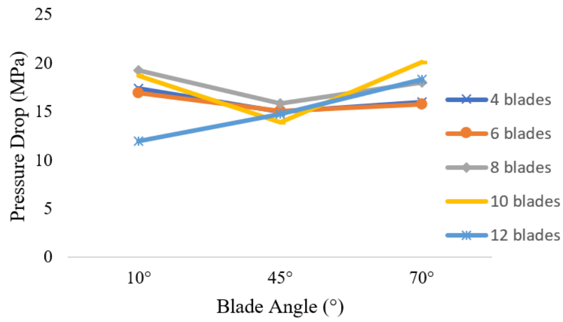
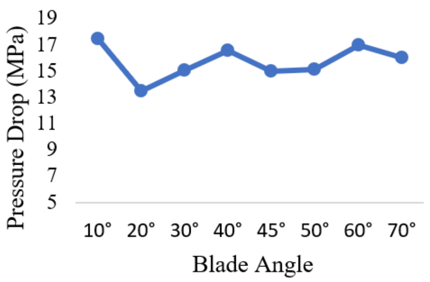


(c)

Figure 7: Effect of blade angle on pressure drop (a) 4 and 6 blades. (b) 6 and 8 blades. (c) 4, 6, 8, 10 and 12 blades.

Effect of Number of Blades on Pressure Drop Performance of the LFSB

Figure 8 (a) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest pressure drop produced for 4 blades is 10° and the lowest pressure drop is 20°. Figure 8 (b) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest pressure drop produced for 6 blades is 60° and the lowest pressure drop is 50°. Figure 8 (c) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest pressure drop produced for 8 blades is 10° and the lowest pressure drop is 45°. Figure 8 (d) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest pressure drop produced for 10 blades is 70° and the lowest pressure drop is 45°. Figure 8 (e) A line chart is used to show the in-depth variation of the different trends on the graph. From the graph above, it is obtained that the highest pressure drop produced for 12 blades is 70° and the lowest pressure drop is 10°.



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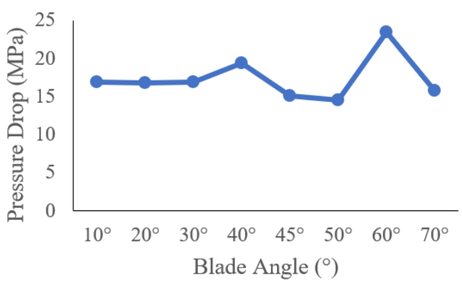

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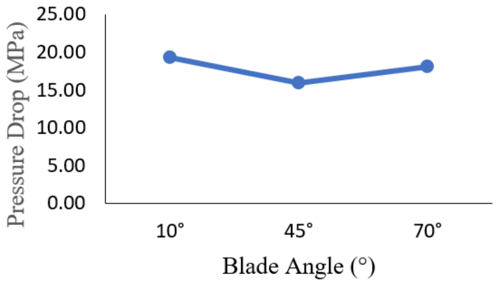

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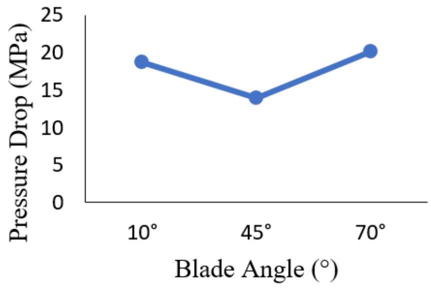

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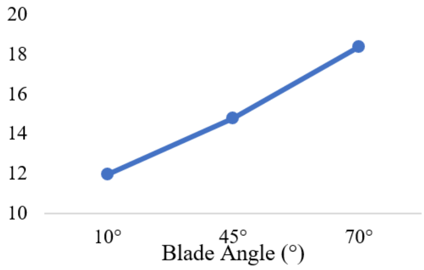

(e)

Figure 8: Effect of number of blades on pressure drop. (a) 4 Blades (b) 6 Blades (c) 8 Blades (d) 10 Blades (e) 12 Blades

Discussion

Comparison of Simulation results with Experimental results

According to this comparison, the 6-blade LFSB inclined at an angle of 50° produced the highest combustion temperature (941°C) for the experimental results. Factors considered include the environmental temperature that had an impact on the combustion temperature. Other environmental factors include the endothermic reaction (energy being absorbed from the surroundings in the form of heat) and exothermic reaction (energy being transferred or released into the system surrounding also in the form of heat). Design techniques and fabrication considerations also had an overall impact on the results obtained. The LFSB used in the experiment had probes for measuring the temperature along the burner length. The temperature from the experimental results used in this comparison is the minimum temperature along the length of the fabricated burner for each of the different blade angle configurations as this had the most similarity to the simulation result. In the case of the simulation results, the 6-blade LFSB inclined at an angle of 30° produced the highest combustion temperature (713.1789°C). The methodology of the simulation on ANSYS Fluent (Non-Premixed Combustion) and the design parameters assumption contributed to the deviation in the results when compared with the experimental results. Unlike the experimental, the lack of endothermic and exothermic environmental factors is a defining factor in the variation of the results.

Comparison of the Number of Blades of the LFSB on the highest temperature and pressure drop

In line with the parametric study, the number of blades on the LFSB was used as a comparison means to obtain the best configuration with the highest temperature and the lowest pressure. In the case of the comparison between the burner with 4 blades and 6 blades at angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°), the highest temperature obtained was the 6 blades inclined at angle 30° with the temperature 713.1789°C. In the case of the comparison between the burner with 6 blades and 8 blades at angles (10°, 45°, and 70°), the highest temperature obtained was the 6 blades inclined at an angle of 70° with the temperature of 687.4539°C. In the case of the comparison between the burner with 4, 6, 8, 10 and 12 blades at angles (10°, 45°, and 70°), the highest temperature obtained was the 10 blades inclined at angle 70° with the temperature 1024.547°C. The lowest pressure drop obtained between the burner with 4 blades and 6 blades at angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°) is 4 blades at 20° (13444413.5927 Pa). In the case of the comparison between 6 blades and 8 blades, the lowest pressure drop obtained at angles (10°, 45° and 70°) is 6 blades at 45° (15088127.99 Pa). In the case of the comparison between the burner with 4, 6, 8, 10 and 12 blades at angles (10°, 45°, and 70°), the lowest pressure drop obtained was the 12 blades inclined at an angle of 10° with the temperature (11973219.92634 Pa).

Comparison of Effect of the Blade Angle of the LFSB on the highest temperature and pressure drop

The highest temperature obtained when the blade angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°) in a 4-blade burner were varied is 4 blades at 20° with a temperature (700.3287°C). In the case of a 6-blade LFSB inclined at angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°), the highest temperature obtained is 713.1789 for a 6 blades burner at 30°. In the case of an 8-blade LFSB inclined at angles (10°, 45°, and 70°), the highest temperature obtained is 687.112 for a 8 blade burner inclined at 10°. The highest temperature obtained when the blade angles (10°, 45°, and 70°) in a 10-blade burner were varied is 10 blades at 70° with a temperature of (1024.547°C). Lastly, in the case of a 12-blade LFSB inclined at angles (10°, 45°, and 70°), the highest temperature obtained is 667.3637 for a 12-blade burner at 70°. The lowest pressure drop obtained in the 4 blades LFSB at angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°) is 4 blades at 20° (13444413.5927 Pa). In the 6 blades LFSB, the lowest pressure drop obtained at angles (10°, 20°, 30°, 40°, 45°, 50°, 60° and 70°) is 6 blades at 50° (14479915Pa). In the 8 blades LFSB, the lowest pressure drop obtained at angles (10°, 45°and 70°) is 8 blades at 45° (15889589.43Pa). In the10 blades LFSB, the lowest pressure drop obtained at angles (10°, 45°and 70°) is 10 blades at 45° (13929679.13Pa). In the12 blades LFSB, the lowest pressure drop obtained at angles (10°, 45°and 70°) is 12 blades at 10° (11973219.93Pa).

CONCLUSION

In this study, the variation of the blade angles and number of blades in the Liquid Fuel Swirl Burner were used in the parametric study to determine the optimum configuration to obtain the highest temperature at the burner outlet and lowest pressure drop that yields effective combustion. The burner was designed with SolidWorks and simulated using the ANSYS Fluent package as noted above. A comparison of the simulation results of the burner with 6 blades and the experimental results of the burner with the same number of blades, both at angles 20°, 30°, 40°, 50°, 60° and 70° was performed to obtain the best results in terms of highest temperature. Likewise, a comparison study of the varying number of blades (4, 6, 8, 10 and 12) at various angles (10°, 45°, 70°) was done to obtain the best results according to the parametric study. In terms of maximum temperature, the best result obtained is a 10-blade LFSB at 70° with a temperature of (1024.547°C) whilst when optimum pressure drop is preferred the most suitable burner configuration is a 12-blade LFSB at 10 with a pressure drop of (11973219.93Pa).

REFERENCES

Akinwonmi, A. S., Adeaga, O. A., & Orhadahwe, T. A. (2023). Investigation of Diesel Blends with Edible Vegetable Oils for Combustion in Swirl Burners. *2023 International Conference on Science, Engineering and Business for Sustainable Development Goals, SEB-SDG 2023, 1,* 1–9. https://doi.org/10.1109/SEB-SDG57117.2023.10124515

Aliyu, A. S., Dada, J. O., & Adam, I. K. (2015). Current status and future prospects of renewable energy in Nigeria. *Renewable and Sustainable Energy Reviews, 48,* 336–346. https://doi.org/10.1016/j.rser.2015.03.098

Benim, A. C., Deniz Canal, C., & Boke, Y. E. (2022). Computational investigation of oxy-combustion of pulverized coal and biomass in a swirl burner. *Energy, 238,* 121852. https://doi.org/10.1016/j.energy.2021.121852

Boushaki, T. (2019). Swirling Flows and Flames. IntechOpen. IntechOpen. https://doi.org/10.5772/intechopen.75295

Clark, N., & Yusoff, K. (2014). Combustion and Society: A Fire-Centred History of Energy Use. In *Theory, Culture & Society* (Vol. 31, Issue 5). https://doi.org/10.1177/0263276414536929

Day, A. R., Ratcliffe, M. S., & Shepherd, K. J. (2003). Boilers and Burners. In *Heating Systems, Plant and Control.* https://doi.org/10.1002/9780470774458.ch2

Dhyani, D., & Phade, S. (2024). A comprehensive study on the design and computational analysis of an air swirl burner. 03006, 0–11.

European Parliament. (2023). *Climate change: the greenhouse gases causing global warming.* https://www.europarl.europa.eu/topics/en/article/20230316STO77629/climate-change-the-greenhouse-gases-causing-global-warming

Ikein, A. A. (2017). Nigeria oil & external exposure : the crude gains and crude pains of crude export dependence economy. *The Business and Management Review, 8*(3), 396–407. http://www.abrmr.com/myfile/conference_proceedings/Con_Pro_65194/conference_74330.pdf

Mansouri, Z., & Boushaki, T. (2018). Experimental and numerical investigation of turbulent isothermal and reacting flows in a non-premixed swirl burner. *International Journal of Heat and Fluid Flow, 72*(June), 200–213. https://doi.org/10.1016/j.ijheatfluidflow.2018.06.007

Martins, J., & Brito, F. P. (2020). Alternative fuels for internal combustion engines. *Energies, 13*(15). https://doi.org/10.3390/en13164086

Jaafar, M. N., Abdul Mookmin, M. S., & Samat, I. (2012). Emission Reduction From Burner System By Varying Swirler Blade Angle. *Jurnal Teknologi, December 2009*. https://doi.org/10.11113/jt.v51.151

Ogbonnaya, C., Abeykoon, C., Damo, U. M., & Turan, A. (2019). The current and emerging renewable energy technologies for power generation in Nigeria: A review. *Thermal Science and Engineering Progress, 13*(August), 100390. https://doi.org/10.1016/j.tsep.2019.100390

Oyewola, O. M., Akinwonmi, A. S., Ajide, O. O., & Salau, T. O. A. (2022). Effect of Swirl on Temperature Decay Function in Straight Blade Liquid Fuel Swirl Burner. *International Journal of Heat and Technology, 40*(2), 527–534. https://doi.org/10.18280/ijht.400220

Oyewola, O. M., Singh, P. M., Akinwonmi, A. S., Ajide, O. O., & Salau, T. A. O. (2022). Thermal Characterization of Straight and Curve Edge Blade Liquid Fuel Swirl Burner. *EUREKA, Physics and Engineering, 2022*(3), 11–19. https://doi.org/10.21303/2461-4262.2022.002157

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection : A review. *Renewable and Sustainable Energy Reviews, 15*(3), 1513–1524. https://doi.org/10.1016/j.rser.2010.11.037

Schmittel, P., Günther, B., Lenze, B., Leuckel, W., & Bockhorn, H. (2000). Turbulent swirling flames: Experimental investigation of the flow field and formation of nitrogen oxide. *Proceedings of the Combustion Institute, 28*(1), 303–309. https://doi.org/10.1016/S0082-0784(00)80224-6

Sengupta, A., Mukherjee, R., & Mishra, V. K. (2021). Performance and emission characteristic of burners: A review. *AIP Conference Proceedings, 2341*(May). https://doi.org/10.1063/5.0051735

Sreenivasan, R., Koli, S. K., & Raghavan, V. (2012). Experimental Study of Effects of Coflow Air and Partial Premixing on Liquid Petroleum Gas Flames. *ISRN Thermodynamics, 2012,* 1–6. https://doi.org/10.5402/2012/202715

Surjosatyo, A., & Priambodho, Y. D. (2011). Investigation of gas swirl burner characteristic on biomass gasification system using combustion unit equipmen (CUE). *Jurnal Mekanikal, 33*(33), 15–31.

Xiao, Y., Cao, Z., & Wang, C. (2018). Flame stability limits of premixed low-swirl combustion. *Advances in Mechanical Engineering, 10*(9), 1–11. https://doi.org/10.1177/1687814018790878

Yang, X. study of combustion and thermal performance in a swirling micro combustor under premixed and non-premixed modes, Zhao, L., He, Z., Dong, S., & Tan, H. (2019). Comparative study of combustion and thermal performance in a swirling micro combustor under premixed and non-premixed modes. *Applied Thermal Engineering, 160* (June), 114110. https://doi.org/10.1016/j.applthermaleng.2019.114110.