IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

The Effect of The Inlet Reactant Direction on Circular Disk Combustor Characteristics

To cite this article: Haslinda Kusumaningsih *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **494** 012051

View the article online for updates and enhancements.



IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 222.93.105.7 on 20/09/2019 at 02:08

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012051 doi:10.1088/1757-899X/494/1/012051

The Effect of The Inlet Reactant Direction on Circular Disk Combustor Characteristics

Haslinda Kusumaningsih, Lilis Yuliati, Rudianto Raharjo, Ragang Aji Wibowo
Mechanical Engineering Department, Engineering Faculty, Brawijaya University, Malang-Indonesia

E-mail: haslinda.kusuma@ub.ac.id

Abstract. Micro-power generator is a micro-scale power generation system that consist of small combustor. Small dimensions combustion chamber produce the unstable flame. It causes high heat loss from the system to the environment through the combustor wall or the exhaust gas channel. This causes the flame difficult to spread and the flame will go out. This study was conducted to determine the effect of inlet reactant direction toward combustion characteristics on a combustor circular disk. Combustor was made of copper and heat resistant glass as a cover to make it easier to observe the flame visualization. Liquefied Petroleum Gas and air were the reactants in this study. The reactant inlet direction was varied tangentially and radially. The results showed the reactant direction of the tangentially inlet produced the most stable flame stability. The tangential flow direction causes the reactants to move to the edge so that reactant gas can fill the combustion chamber. And with the swirl flow in the flame combustion chamber, it can spin longer before exiting to the exhaust gas, thus increasing combustion residence time in the combustion chamber and combustion will be more perfect. Likewise, the highest flame temperature is in the reactants direction tangentially. However, the flame temperature will decrease as the equivalent ratio increases in a constant fuel flowrate state.

Keywords: *Meso-scale combustor, combustor circular disk, micro power generator, combustion characteristics.*

1. Introduction

Micro-power generator is a micro-scale power generation system. Micro-power generator is composed of two main parts, namely micro-scale combustor or meso-scale combustor which is used as an energy source and a module to convert heat energy into electrical energy in the form of (thermo photovoltaic or thermoelectric). Based on the shape, combustor can be distinguished into three types, namely disk-type, tube-type and swiss roll. Disk-type combustor has the best thermal efficiency compared to other combustor shapes, and is easier to use because the surface is flat so it is easier to apply with thermoelectric. Micro-scale combustion has dimensions of combustion characteristics of less than 1 mm, while meso-scale combustion is more than 1 mm [1].

Meso-scale combustion has a weakness, namely the small dimensions of combustion chamber which results in unstable flames which raise high heat loss from the system to the environment through combustor walls and exhaust gases. Flame is difficult to propagate and goes out if heat loss is large [2]. In addition, the small dimension of the combustion chamber causes the reactant residence time to be

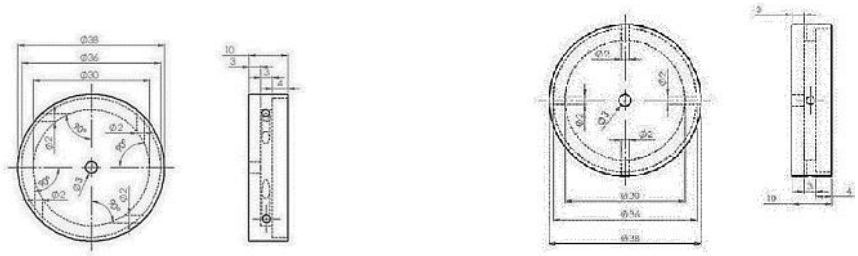
Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

shorter [3]. Efforts to increase the reactant residence time in meso scale combustion can be performed by creating a swirling reactant flow because the flame swirl flow can move around in the combustion chamber longer before exiting to the exhaust gas channel and the flame is more stable [4].

Reactant swirl flow can be generated by adjusting the reactant flow direction at meso-scale combustion, the tangentially reactants direction causes the formation of swirl reactants and the longer the reactant residence time in the combustion chamber, so that reactant can burn more perfectly and the flame will be more stable [5]. For this reason, in order to obtain good combustion characteristics on the meso scale combustion, it is necessary to conduct a research on the effect of the inlet reactant direction on the combustion characteristics of the circular disk combustor.

2. Method

This study used a circular disk of combustor type with the inlet reactant direction tangentially and radially. The reactants used in this study were LPG and air from the compressor.



(a) (b)

Figure 1 Dimension of Circular Disk Combustor (a) tangential disk combustor (b) radial disk combustor

Air discharge (Q_f) and fuel (Q_a) were varied at ϕ = 0.8, 1, 1.2. The Combustor was made of copper and has a diameter of 30 mm. The number of inlet channels was 4 channels, the tangential and radial inlet combustor angles were 90° and 0^0, respectively in Figure 1a and b. The flame stability in the form of the maximum limit of fuel discharge and the minimum limit of fuel discharge, combustor wall temperature and flame shape visualization were the results of the study.

Research data collection began by flowing fuel and air which had been regulated by each discharge and observed through a flow meter as in Figure 2, then fuel and air were mixed in the mixing chamber. After the fuel and air were mixed, the mixture of fuel and air was flowed into the combustor and then the lighter was lit so that the fire ignites.

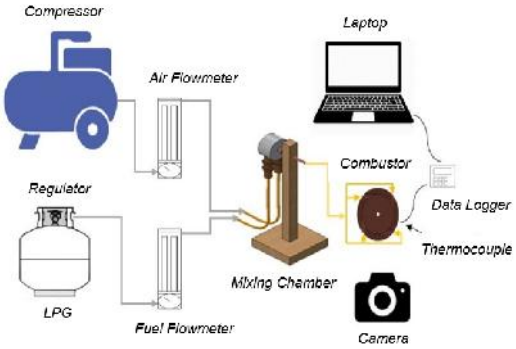


Figure 2 Research Installation Scheme

After the flame was flaming stably, data collection of combustor wall temperature and flame visualization could be collected, while the flame stability data was collected from a steady flame that flaming for more than 3 minutes. The data collection point of circular disk combustor temperature wall was located along the combustor diameter with each measurement point distance of 1 mm as in Figure

3. Visualization image was captured using a camera with perpendicular shooting angle to circular disk combustor direction and within ± 30 cm in distance. Combustor wall temperature data was measured using thermocouple and processed by a data logger, then stored on the laptop.

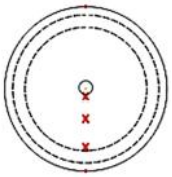


Figure 3 Point Location of Data Collection on Combustor Wall Temperature

3. Results and Discussion

3.1. Flame stability

Flame on the circular disk combustor with an inlet reactant radial direction can only light up if there is a lighter in the combustion chamber. However, when the lighter was removed from the combustion chamber, the flame instantly went out. So that data collection of flame stability on a combustor circular disk with radial inlet reactant cannot be obtained because the flame cannot ignite stably. Conversely, the flame can be stably lit even though the lighter was removed from the combustion chamber on the combustor circular disk with the tangential inlet reactant, the flame stability data can be seen in Figure 4.

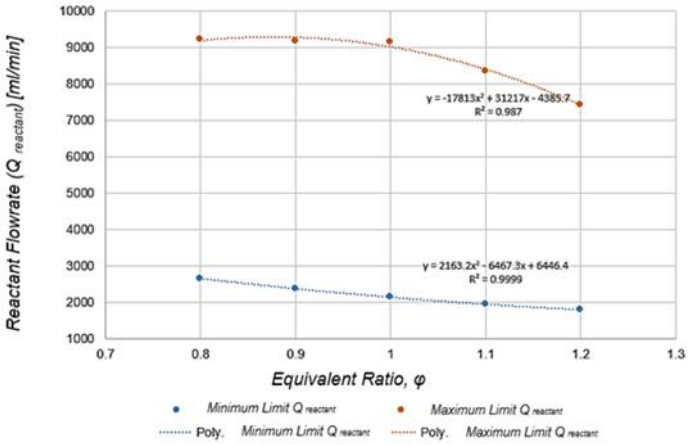


Figure 4 Correlation between Reactant Flowrate with Equivalent Ratio on a Circular Disk Combustor with a Tangential Direction Reactant Inlet

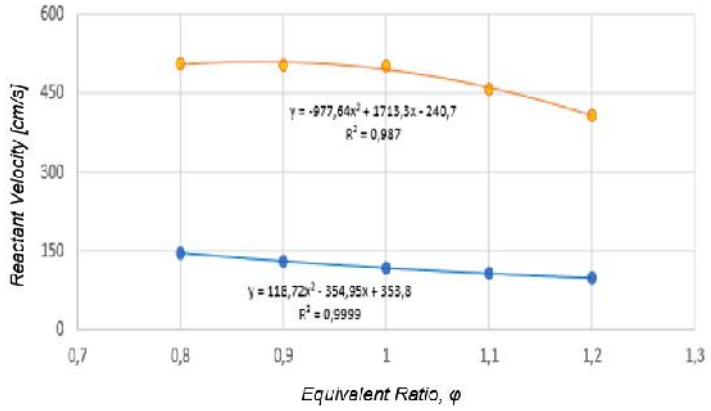


Figure 5 Correlation between Equivalent Ratio with Reactant Velocity at the Circular Disk Combustor with the Tangential Direction Reactant Inlet

The flame can be lit stably on a circular disk combustor with a tangential inlet reactant with an equivalent ratio of 0.8 to 1.2. The lowest reactant flowrate was 1798 ml/min and the highest was 9220 ml/min. This happens because the reactants can stay longer in the combustion chamber, so that the reactants can burn more perfectly. In addition, heat loss occurs lesser so the flame can be more stable.

Besides being shown by the minimum and maximum limits of reactant flowrate, the flame stability can also be indicated by the reactant velocity data on the equivalent ratio variation. Based on Figure 5, it is known that the greater the equivalent ratio, the reactant speed decreases. The highest reactant velocity was found in the equivalent ratio of 0.8 which was 506.04 cm/s, while the lowest reactant velocity was found at a ratio of 1.2 of 98.69 cm/s. This is because less air available to burn fuel ($\phi > 1$), therefore the reactant speed tends to be low.

3.2. Flame Visualization

The flame on the combustor circular disk with the radial direction reactor inlet shown in Figure 6 cannot ignite stably because the reactants velocity that coming out to the exhaust gas channel is higher than the flame speed. The lighter color of the flame indicates reactants distribution in the zone is greater than in other regions. Meanwhile, the fainter flame color is diffusion from the radial direction reactant. Flame cannot ignite at an equivalent ratio of 1.2 because the fuel flowrate was low which results in the reactants being unable to fill the combustion chamber, so combustion cannot occur.

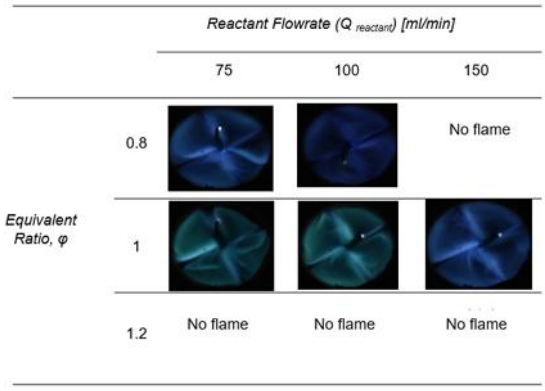


Figure 6 Flame Visualization on Circular Disk Combustor with a Radial Direction Reactor Inlet.

This proves that as the fuel flowrate increases, the more fuel reacts and burns, resulting in higher fire temperatures followed by increased combustor temperatures. Figure 7 also shows the flame visualization on the combustor edge has a lighter color than the middle side, this shows that the reactants distribution that occur is more at the combustor edge compared to the center.

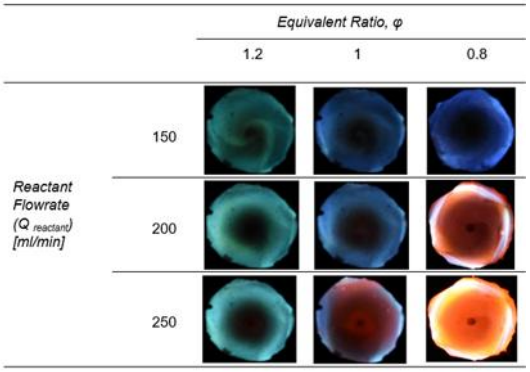


Figure 7 Flame Visualization on Circular Disk Combustor with a Tangential Reactant Inlet

In addition, the lesser the fuel flowrate entering the same equivalent ratio, the greater the dark colored area. This is because the reactants have burned before reaching the center point of the combustor.

Conversely, the higher the fuel flowrate, the greater the combustion reaction zone so that the darker area gets narrower because the fire filling all combustor parts or chamber.

3.3. Combustor Wall Temperature

Table 1 presents the combustor wall temperature data on the circular disk combustor with the tangential inlet reactant at the fuel discharge of 75 ml/minute and 150 ml/ minute. There are three temperature data collection points as shown in Figure 3. Based on Table 1, the temperature at point 2 was the highest compared to other data collection points at each variation of the fuel discharge and equivalent ratio. This is because the position of the two points is in the center of the combustion chamber so that the resulting combustion is more evenly distributed.

The greater the equivalent ratio ($\phi > 1$) at the same fuel discharge causes the combustor wall temperature to decrease further. This is due to the less air available to react with fuel so that the reactant speed tends to be low and the temperature decreases. In applying a micropower generator, a high combustor wall temperature is needed, so that more heat energy is converted into electrical energy by thermoelectric.

Table 1 Circular Disk Combustor Wall Temperature Data with Tangential Direction Inlet Reactant

Flowrate	Point	Φ 0,8	Φ 1	Φ 1,2
75 ml/min	1	195,59	188,37	174,06
	2	199,12	190,68	185,31
	3	171,30	165,22	158,43
150 ml/min	1	339,26	293,91	230,74
	2	351,78	303,03	236,39
	3	302,19	253,26	213,10

4. Conclusion

The conclusions obtained from the research on combustion characteristics in the tangential and radial circular disk combustor are as follows:

1. Combustion in the inlet tangential of disk combustor results in a more stable and evenly distributed combustion compared to the *radial inlet disk combustor*
2. The result of flame form visualization becomes increasingly bright and wide along with the increase in reactant velocity, whereas the area of the flame decreases as the equivalent ratio increases.
3. Tangential disks combustor has evenly uniform combustion wall temperatures that have high temperatures compared to *radial disk combustor*

REFERENCES

[1] Maruta, K. 2011. Micro and Mesoscale Combustion. *Proceedings of The Combustion Institute*, Vol. 33. Issue 1. pp: 125-150.
[2] Katsuyoshi, T., Soichiro, K., Taku, M. & Toshiyuki, S. 2009. Development of The Micro Combustor. *Engineering Review*. Vol. 42 No 2. pp: 97-101.
[3] Cozzi. F., Olivani A., Coghe A., Luchetti A., Tonazzo F. 2006. *Experimental Investigation of a Mesoscale Combustor*. Milan: Politecnico di Milano.
[4] Khaleghi, M., Hosseini, S.E., Wahid, M.A. 2015. Vortex Combustion and Heat Tranfer in Meso-Scale with Thermal Recuperation. *Journal of International Communications in Heat and Mass Transfer*. Vol. 66. Pp 250-258.
[5] Febrianto, W., Yuliati, L., Hamidi, N. 2015. Karakteristik Pembakaran Heksana pada Mesoscale Combustor dengan Preheated Multiple Tangential Fuel Inlet. Thesis. Malang: Brawijaya University