THE ROLE OF PERFORATED PLATE AND ORIENTATION OF THE MAGNETIC FIELDS ON COCONUT OIL PREMIXED COMBUSTION
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PERANAN PELAT BERLUBANG DAN ARAH MEDAN MAGNET PADA PEMBAKARAN PREMIX MINYAK KELAPA

Dony Perdana[*1)]; Satworo Adiwidodo[2)]; Subagyo[1)]; Wigu Ardi Winarko[3)]
[1)] Universitas Maarif Hasyim Latif, Department of Mechanical Engineering, Indonesia;
[2)] State Polytechnic of Malang, Department of Mechanical Engineering, Indonesia;
[3)] University of Jember, Department of Mechanical Engineering, Indonesia;
Tel: +6285225487839; E-mail: dony_perdana@dosen.umaha.ac.id
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ABSTRACT
The research was carried out to determine the effect of variations in perforated plates and the direction of the magnetic field on the flame properties of coconut oil in premixed combustion. The results show that the variation of the perforated plate has a significant impact on the stability and temperature of the flame. The 11-hole perforated plate produces a more stable flame at higher reactant velocities. The magnetic field plays a very important role in increasing the laminar combustion speed on the 7-hole perforated plate with a temperature of 659°C because the electron spin magnetic field accelerates the breaking of the carbon chain bonds on the fuel.

ABSTRAK
Penelitian ini dilakukan secara eksperimen untuk mengetahui pengaruh variasi pelat berlubang dan arah medan magnet terhadap karakteristik nyala api minyak kelapa murni pada pembakaran premixed. Hasil penelitian ini menunjukan bahwa variasi pelat berlubang mempengaruhi stabilitas dan temperatur nyala api. Pelat berlubang 11 menghasilkan nyala api yang lebih stabil pada kecepatan reaktan yang lebih tinggi. Medan magnet sangat berperan terhadap peningkatan kecepatan pembakaran laminar pada pelat berlubang 7 dengan suhu 659 ^{0}C karena spin elecrton medan magnet mempercepat terputusnya ikatan rantai karbon pada O_2 dan bahan bakar.

INTRODUCTION
The use of petroleum fuels increases continuously every year resulting in the depletion of world oil reserves. Production of renewable fuels for energy purposes has seen a rapid increase in recent years *(Hunicz J. et al., 2020)*. Several researchers use vegetable oil as a substitute for fossil fuels. The use of vegetable oils directly in the engine is very complicated in that the high viscosity and low volatility causes a lot of sludge in the engine, in the injectors and piston rings *(Leung D.Y.C. et al., 2010)*. The issue has been described as clogged filters, deposits in the combustion chamber *(Murugesan A et al., 2009)*. There are various solutions proposed:

- blending
- preheat,
- exhaust gas recirculation
- modifications.

its high availability and is included in category of sustainable energy resources *(Mat S.C. et al., 2018; Pham D.T.T. et al., 2018)*. Coconut oil has been researched as a diesel substitute fuel because, coconut oil fatty acids have a long-chain carbon that is similar to the molecular structure of diesel *(Nanlohy H.Y. et al., 2018)*. The results showed that the preheated coconut oil could be put in use directly to substitute diesel without requiring engine modification *(Malik M.S.A. et al., 2017)*. Coconut oil has many advantages when compared to petroleum, including low emissions and high availability in tropical countries. Coconut oil, on the other hand, has a higher density, surface tension, flash point, and viscosity, yet its volatility is lower than that of diesel. Because of the limitations of vegetable oils, some researchers use magnets to increase combustion efficiency and reduce emissions.

The high intensity of the magnetic fields can sever the bond of hydrocarbon molecules, causing the fuel atomization process to be more flammable. This affects combustion efficiency and reduces pollutant emissions *(Jain S., 2012)*. If a magnetic field is applied with sufficient intensity and for a suitable period of time, the viscosity of the fuel will decrease significantly *(Oommen L.P. and Kumar G.N., 2019)*. The magnetic field causes a decrease in the surface tension (*Khedvan A.V.G., Gaikwad V.A., 2015*). The intensity of the magnetic field of 1 Tesla increases thermal efficiency by 7% and the power by 16.4% *(Habbo A.R.A. et al., 2011)*. The use of a 4000 gauss magnetic field with used cooking oil increases the combustion efficiency by 12%, while carbon dioxide, carbon monoxide, hydrocarbon decrease by 31%, 37%, 25%, respectively (*Mahfouz A. et al., 2017)*. The perforated plate is considered to be one of most important techniques and the oldest used in combustion applications. Combustion instability has become one of the main challenges in the design and development of gas turbines, liquid rockets and industrial furnaces *(Poinsot T., 2017)*. In the hollow burner, a cellular flame is formed by the diffusion flame radiative combustion of coconut oil, glycerol, and kapok seed oil. *(Wirawan I.K.G. et al., 2014)*. Six modes of turbulent flame propagation were observed downstream on all sides in a perforated plate furnace *(Zhou L. et al., 2018)*. The effect of recirculation of exhaust gases provided by the perforated plate reduces nitrogen oxides, carbon monoxide emissions and increases thermal efficiency. Nitrogen oxides were found to be lower than when the boiler was operating at an equivalency ratio of 0.90 with 15% exhaust gas recirculation, and the thermal efficiency was 4.7 percent greater. *(Yu B et al., 2013)*. Nitrogen oxides and carbon monoxide pollution could be calculated at a burner maximum heat capacity of 32 kcal/hour *(Lee P.H., Hwang S.S., 2013)*.

The relationship between engine performance and combustion stability has not been frequently explored or examined by researchers. Furthermore, the effect of perforated plates and the direction of the role of magnetic fields in combustion stabilization products require more investigation. This study aims to review the role of variations in the perforated plate and the permanent magnet field direction on behaviour, stability and characteristics of the flame in the combustion process. Flame stability applications are useful in the efficient and stable combustion of military aircraft, gas turbines, industrial furnaces, and industrial oil burners in long-term use. However, further research is needed, especially for the efficiency of radiant heat energy productions, and the noise generated by combustion.

MATERIALS AND METHODS

The vegetable oil tested was coconut oil obtained from commercial products. Vegetable oil has fatty acid compositions, physical, chemical, glycerol, and gum properties, which have been studied previously *(Perdana D. et al., 2018)*.

Set up for the experiment

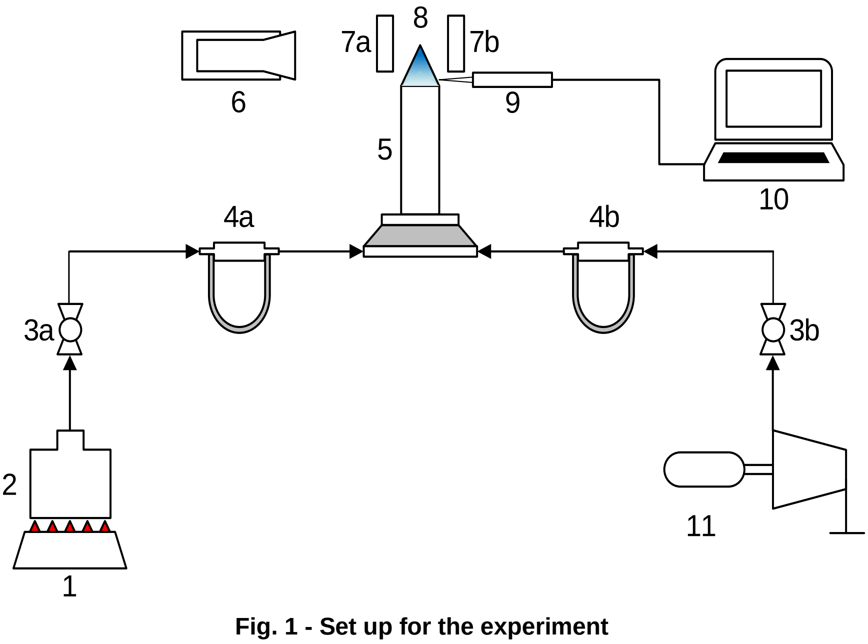

Fig. 1 - Set up for the experiment
1 - stove; 2 - boiler; 3 - valve; 4 - flow control; 5 - burner; 6 - high-speed camera; 7 - permanent magnet; 8 - flame; 9 - thermocouple; 10 - data logger; 11 - compressor

The installation is schematically shown in Fig.1. Coconut oil (600 ml) is filled into the boilers (2), then heated with burner (1) to evaporate at a temperature of 300ºC and the pressure is kept constant at 4 bar. The evaporating valve is open while the air inlet is close. The next step is to slightly open the air inlet valve (3) and the height difference is recorded in the flow control (4). Differences in fuel flow control are recorded and kept constant. The evaporated coconut oil is then mixed with air in the combustion chamber (5). Combination reactants are passed to a nozzle with d=18 mm, and then, the fire on the burner is ignited. The flame gradually becomes a mixed flame as the amount of air in the mixture increases. Magnetic rectangles (7a and 7b) with north and south poles, respectively, are then used to apply a magnetic field to the flame. Premix flame (8) which is a form at the edge of the burner is recorded until the fire is extinguished using a camera with a high frame rate of 320 fps (6). The data logger is connected to a K type thermocouple (9) placed at 2 mm above the burner tip to record the temperature generated in the computer memory (10) as shown in Fig.2.

Position of magnets and thermocouple

Two rectangular magnets are placed on a stand made of aluminium plate and fastened for easy removal and re-attachment changing the direction of the magnetic fields NN and SN. (Fig.1).

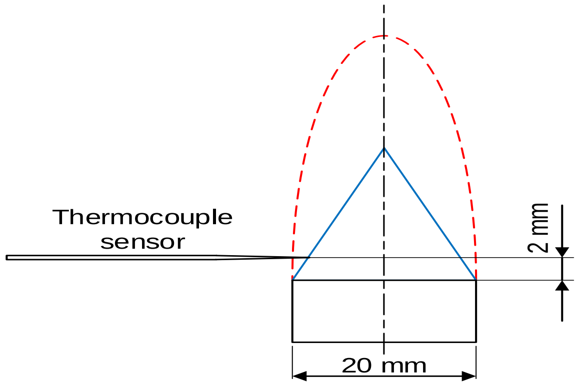

Fig. 2 - Thermocouple position

Variation of perforated plate

The variation of the perforated plate lies in the number of holes 7, 9, and 11, each with a diameter of 2 mm, while the outer diameter is of 20 mm as shown in Fig.3. The perforated plates are made of stainless steel with a thickness of 2 mm.

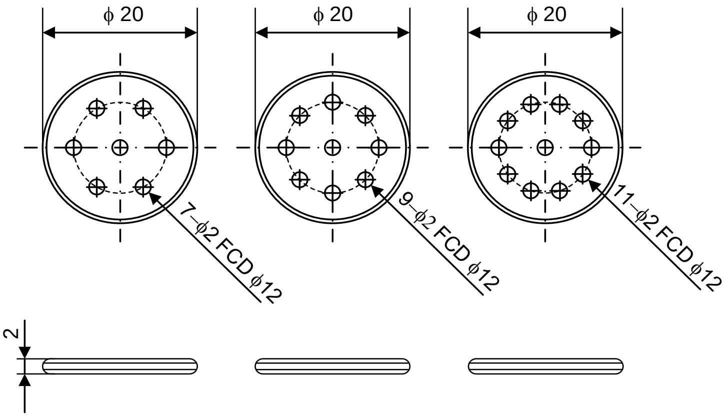

Fig. 3 - Perforated plates 7; 9; and 11

RESULTS AND DISCUSSION

Characteristics of the flames

Fig.4 and Fig.5 each show a premix flame of coconut oil with variations in the perforated plate and the magnetic field orientation. Variations of perforated plates with 7, 9, and 11 holes in the repulsive magnetic field indicate incomplete combustion. This is indicated by a small yellow colour at the top of the flame at an equivalent ratio of 2.07. While in the magnetic field of attraction at the same equivalent, combustion occurs completely which is indicated by the dominant colour of the blue flame. This is due to the effect of high and faster diffusion rates than in reactant fuel rates at various perforated plates.

The addition of a magnetic field to the flame affects the combustion reaction. This happens because O_2 which is paramagnetic will contribute to moving in the direction of the magnetic fields while water, which is diamagnetic moves against the magnetic field orientation. The repulsive magnetic field indicates incomplete combustion; this is indicated by the formation of a yellow colour at the top of the flame.

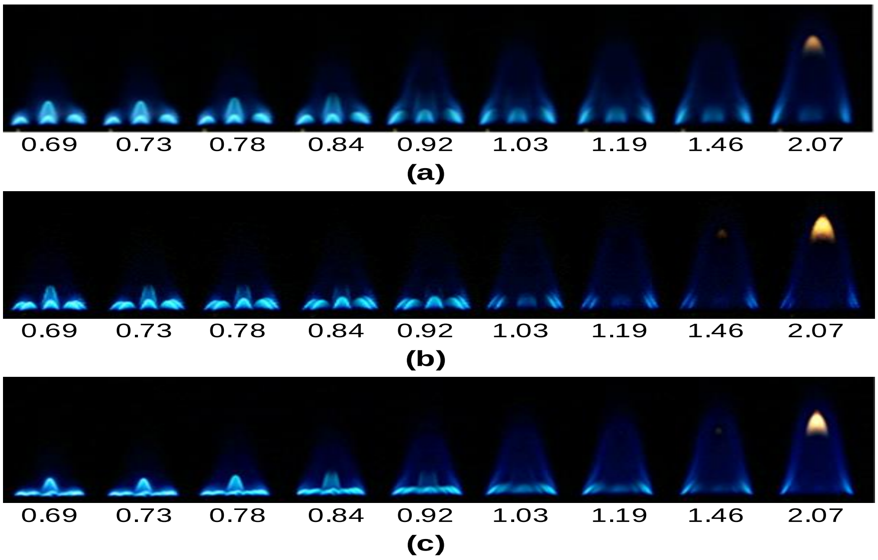

Fig. 4 - Characteristics of the flame of coconut oil at an equivalence ratio at the repulsive magnetic field (N-N): 7-hole perforated plate (a); 9-hole perforated plate (b); and 11-hole perforated plate (c)

The direction of the repulsive magnetic field attracts H_2O into the flame, while O_2 is pushed out. On the other hand, the magnetic field is attracted, H_2O is pushed out and O_2 is drawn in the flame, causing the dominant flame colour to be blue in all equivalence ratio ranges (Fig.5). The significant impact seen in Fig.4 and Fig.5 is the increase in the stability of the flame from an equivalence ratio of 0.69 to 0.65; the flame formed is blue.

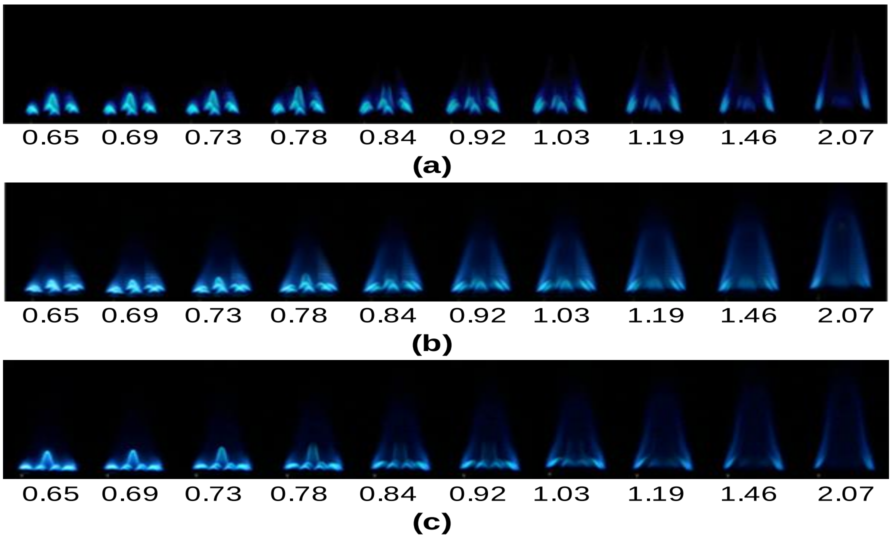

Fig. 5 - Characteristics of the flame of coconut oil at an equivalence ratio at the attractive magnetic field (S-N): (a) - 7-hole perforated plate; (b) - 9-hole perforated plate; (c) - 11-hole perforated plate

The laminar flame speed

Fig.6 estimated the laminar flame speeds of coconut oil from the flame angle in Fig.4 and Fig.5. Maximum laminar flame speed occurs at an equivalent ratio of about slightly above 0.65. The maximum flame speed perforated variation with the attractive magnetic field occurs in the mixture which is richer than the repulsive magnetic field. In the variation of the number of holes in the perforated plate, maximum flame speed occurs on the 7-hole perforated plate, while the minimum flame speed occurs on the 11-hole perforated plate.

This is due to the difference in the cross-sectional area of each variation of the perforated plate. With the same fuel flow and airflow rate that continues to increase gradually, the different cross-sectional area of the perforated plate causes the reactants in the mixing chamber to be easier to exit through the perforated plate when the cross-sectional area is large. When the cross-sectional area of the perforate is smaller, the resistance of reactants to exit becomes greater so that reactants accumulate in the burner. The build-up of reactants in the burner causes the reactants to be forced out at a higher speed. This will affect the high or low combustion speed of each perforated plate. With the addition of a magnetic field, the laminar flame speed increases the equivalence ratio is leaner because the electrons are more energetic and the molecules in the reactants are more aligned. The difference in the magnetic field orientation greatly affects the combustion speed.

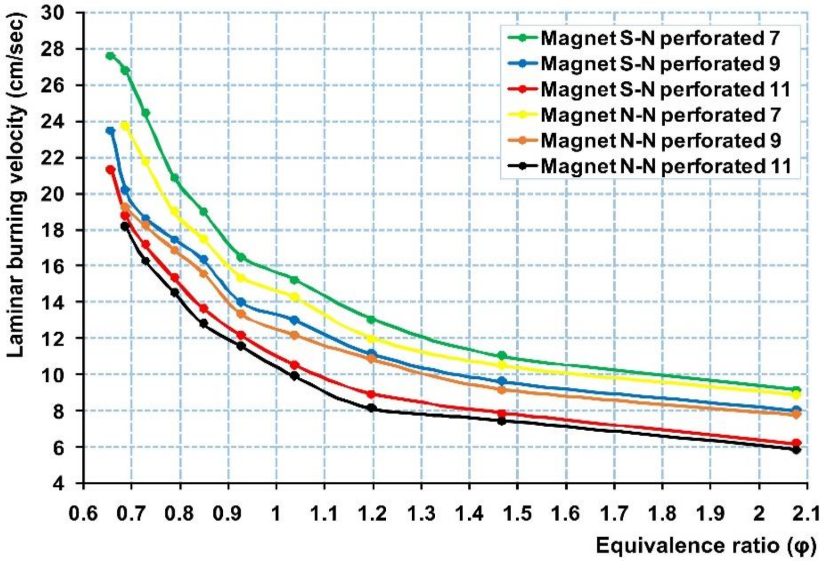

Fig. 6 - The laminar flame speed of coconut oil in terms of equivalent ratio with variations of the perforated plate and magnetic field

In the perforated plate, the burning speed is higher when a magnet is added than without a magnet. This happens because the electrons in the reactants are already at a high speed; with the addition of a magnetic field, the electrons will move more energetically.

Flame temperature

Fig.7 shows the flame temperature of the premix combustion on various perforated plates and the orientation of the magnetic field poles. It can be seen that the trend of decreasing temperature is inversely proportional to the laminar flame speed. This is because flamed speeds express the speeds of combustion, namely heat release rate. In the perforated plate variation, the repulsive magnetic field produces a lower temperature rise than the attractive one. The repulsive field affects the temperature to decrease in the lean mixture, this illustrating that the flame is not stable.

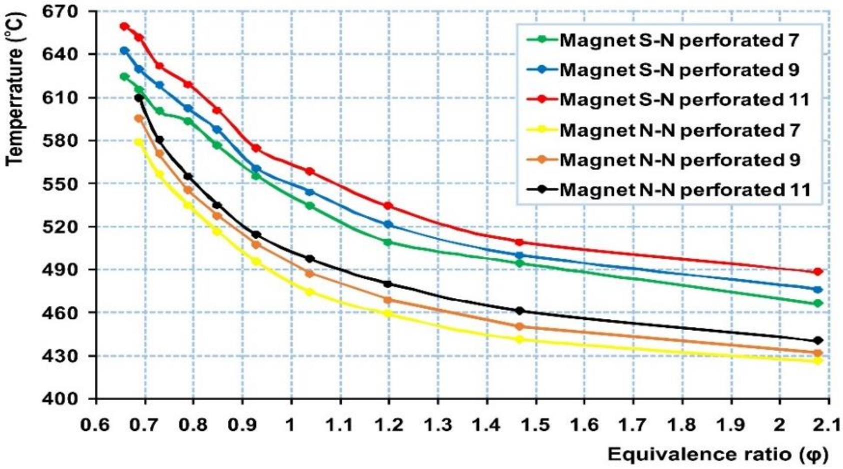

Fig. 7 - Flame temperature of coconut oil concerning equivalence ratio with variations of the perforated plate and magnetic field

In the case of the 11-hole perforated plate, the combustion speed tends to be lower so that no reactants are released before burning out. This causes the resulting temperature to be higher. The opposite occurs in 7 and 9-hole perforated plates. Besides that, fewer holes cause more heat absorption by the walls during combustion. With increasing flame temperature, oxygen which has double bonds will break its bonds in the reaction zone. When the oxygen bonds are broken, a recombination reaction will occur to form CO_2 and H_2O bonds accompanied by the release of heat and light. The addition of the number of perforated plates and the magnetic field in the flame will accelerate the breaking of the carbon chain bonds, causing excess O_2 to be absorbed during combustion so that the temperature of the resulting flame increases.

Flame height

The flame height of the premix combustion on various perforated plates and the orientation of the magnetic field poles are shown in Fig.8. The flame of the perforated plate with the repulsive magnetic field is higher than the attractive magnetic field. This indicates that the flame of a perforated plate with a repulsive magnetic field is less stable than an attractive magnetic field. A higher flame indicates that it tends to be less stable because it has a greater strain.

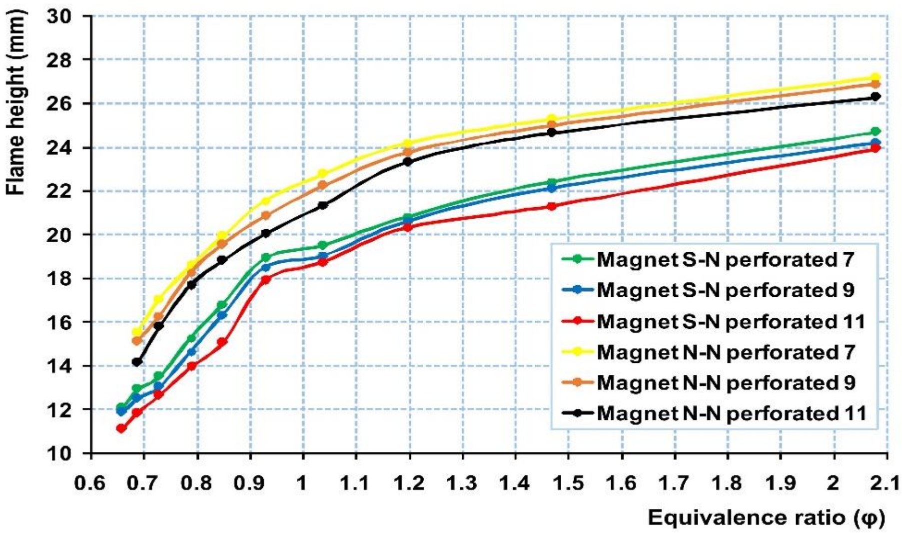

Fig. 8 – Flame height of coconut oil to equivalent ratio with variations of a perforated plate and magnetic field

The attractive magnetic field has a greater effect on shortening the flame. The magnetic attraction makes the electrons very energetic so that an increase in reaction speed could compensate for the speed of diffusion (see Fig.4 and Fig.5). This is also related to the burning speed on the perforated plate variations. When opposed to a sluggish combustion reaction, a quick combustion reaction produces a smaller flame *(Valente O S et al., 2012)*. With a high attractive magnetic field, the flame tends to be higher than the repulsive magnetic field. This can happen possibly because there is still space left on the perforated plate so that when the magnetic field attracts, the flame expands closer to the magnetic field so that the flame formed becomes lower. Meanwhile, when the direction of the magnetic field repels, the flame tends to move away from the magnetic field so that the flame formed is thinner and longer.

CONCLUSIONS

Premix combustion is observed from a burner with perforated variations and magnetic field orientation.

The higher the intensity of the magnetic field, the more energetic the spin of the electrons, causing hydrogen protons to break on the fuel. The magnetic field has an important role in increasing laminar combustion speed as well as the resulting temperature because the electron spin accelerates the breaking of carbon chain bonds and absorbs oxygen during combustion. The direction of the magnetic field poles has an important role in transporting oxygen and the temperature carried by the water produced by the combustion reaction, thus causing more stable and complete combustion. The number of variations of the perforated plate affects the stability of the flame, the higher the number of perforated plates, the more turbulence is produced, causing the molecular bonds of fuel to break. The combination of the number of perforated plates and the right direction of the magnetic field will produce a perfect combustion reaction quality.

However, this study still has shortcomings related to the number of perforated plates and types of vegetable oil, and the intensity of the magnetic field. Further research is needed for its development and applications on the machines, to get some data for advancements in industry and transportation.

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