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THE EFFECT OF USING A HEAT COLLECTION FILTER ON THE EFFICIENCY OF HEAT ABSORPTION FROM THE FLAME OF LPG GAS FUEL

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ABSTRACT

One of the uses of heat from fuel combustion is for the needs of cooking activities. The heat from the combustion reaction heats the surface of the pan, this occurs in the process of heat transfer by convection on the surface of the pan. The rooting reaction of LPG fuel produces a flow of combustion gas with a high flow speed. This will have the consequence that the heat wasted is very large while the absorbed is very small in the process of heating the surface of the pan. To increase heat absorption by the surface of the pan can be done by inhibiting the flow when the fire touches the surface of the pan. This study will examine how the effect of using a heat collection filter on the heat absorption efficiency of the flame of LPG fuel gas and aims to compare the heat absorption efficiency of a fuel gas flame using a heat collection filter with no heat collection filter (conventional). This study uses independent variables in the form of heat absorption without a heat collection filter and with a heat collection filter, as well as variations in LPG mass flow rate rate. While the dependent variable observed is the heating time to obtain heat absorption efficiency. The results showed that convection heat absorption using a heat collection filter has a better efficiency than without using a heat collection filter at various LPG mass flow rate rate, where the efficiency increases up to 4%.

Keywords LPG fuel gas; convection; heat collection filter
Paper type Research paper

INTRODUCTION

Indonesia with a very large population requires a very large energy supply. One of the uses of energy in everyday life is the combustion of fuel that produces heat for household needs [1]. With the depletion of fuel oil availability, more are now switching to LPG (50% Propane and 50% Butane) type fuel gas[2]. At a time when the availability of gas fuel will also be depleted and expensive so research needs to be pursued that can increase the efficiency of using gas fuel in everyday life.

One of the uses of heat from fuel combustion is for the needs of cooking activities. The heat from the combustion reaction heats the surface of the pan, this occurs in the process of heat transfer by convection on the surface of the pan. Gas fuels have a higher calorific value than liquid and solid fuels and are more flammable[3]. With these characteristics, it will produce a flow of gas from the cultivation with a high flow speed. This will have the consequence that the heat wasted is very large while the absorbed is very small in the process of heating the surface of the pan. To increase heat absorption by the surface of the pan, it can be done by inhibiting the flow when the fire hits the surface of the pan by using a heat collection filter[4]. This study aims to compare the heat absorption efficiency of LPG gas fuel flame using a heat collection filter with no heat collection filter (conventional).

According to Holman[5] says that it is well known that hot metal plates cool faster when placed in front of a fan than when placed in quiet air. We say that if it is convected or turned outward, and this process is called heat transfer by convection, it may have given an idea of what happens in this heat transfer process. But this picture still has to be developed in order for us to carry out adequate analytical processing on this issue. For example, we already know that the speed of air blown into this hot plate will affect the rate of heat transfer [6]. But does this influence take place in a straight proportion, meaning that if the speed is doubled, will the heat transfer rate also be twice as fast. It

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can also be estimated that the rate of heat transfer would be different if the plate was cooled with water instead of air.

The flow velocity is zero on the plate face as a result of viscous action. Therefore, the velocity of the fluid layer on the wall is zero, so here heat can only move by conduction only. So we can calculate heat transfer, namely with the equation q = -kA ∂T / ∂x, using the thermal conductivity of the fluid and the temperature gradient of the fluid on the wall. If heat flows by conduction in this layer, we are talking about convection heat transfer and need to take into account the velocity of the fluid, that is, that the temperature gradient depends on the speed of the fluid carrying heat from it a high speed will cause a large temperature gradient as well, and in the analysis we need to develop an equation that connects the two quantities [7]. But the physical mechanism on the wall is in the form of a conduction process.

In order to express the effect of conduction as a whole, Newton's law of cooling is used: q = h.A(Tw - T∞). Here the heat transfer rate is related to the overall temperature difference between the wall and the fluid, and the surface area A. The quantity h is called the convection heat-transfer coefficient, and the equation q = h.A (Tw - T∞) is the basic formula. We can perform analytical calculations on h for several systems. For complex situations h must be determined by experiment. The coefficient heat transfer is sometimes called film conductance because of its relationship with the conduction process in a thin layer of stationary fluid on the wall face. From the equation q = h.A (Tw- T∞) we can see that the unit h is watts per meter per degree celcius when the heat flow is in watts.

From the discussion above, it can be expected that convection heat transfer depends on the viscosity of the fluid in addition to its dependence on the thermal properties of the fluid (thermal conductivity, specific heat, density). This is understandable because viscosity affects speed profile, and therefore, affects the rate of energy transfer in the wall area. If a hot plate is left in the air without any external source of movement, it will move as a result of the density gradient near the plate. This event is called natural convection or free convection to distinguish it from forced convection that occurs when the plate is blown on the plate with a fan. The phenomenon of condensation is also included in the group of convection heat transfer problem [8].

The Nusselt number is the ratio of convection heat transfer and normal conduction to the limit in the case of heat transfer on the surface of the fluid. Nusselt numbers are dimensionless units named after Wilhelm Nusselt. Conductive components are measured under the same conditions as convection under conditions of stagnant or immobile fluids. Heat transfer between the boundary of solids and fluids occurs due to a combination of conduction and mass transport. The speed of energy transfer depends on the movement on energy transfer depends on the mixing motion of fluid particles. To transfer heat by convection through a fluid at a certain rate, a greater temperature gradient is required in areas where velocities are lower than in areas where velocities are high. The discussion above leads to a way to determine the rate of heat transfer between solid walls and fluids, because in the intermediate plane (that is, at y = 0) heat flows only by conduction, then the heat flow rate can be calculated from the equation:

$$\mathrm{q} = -k\,A \left.\frac{\partial T}{\partial y}\right|_{\mathrm{y}=0} \qquad (1)$$

For engineering purposes, understanding the efficiency of convection heat transfer will be easier. By equating the above equation with Newton's law of cooling or the equation $q^n = h\,(T_\omega - T_\infty)$ we get:

$$q = -k\,A \left.\frac{\partial T}{\partial y}\right|_{\mathrm{y}=0} \bar{h}\,A\,(T_\omega - T_\infty) \qquad (2)$$

Because the magnitude of the temperature gradient in the fluid will be the same regardless of the reference temperature, then we can write $\partial T = \partial\,(T - T_\omega)$ by entering a dimension of the characteristic length of the system X to show the geometry of the object from the safe heat flow, we can write the equation $q = -k\,A \left.\frac{\partial T}{\partial y}\right|$ y = 0 $\bar{h}\,A\,(T_\omega - T_\infty)$ above in dimensionless form as:

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$$\frac{\overline{h}x}{k} = \frac{-\frac{\partial T}{\partial y}\Big]_{y=0}}{\frac{T\omega - T_\infty}{x}} = \frac{\partial\left(\frac{T_\omega - T}{T_\omega - T}\right)}{\partial\left(\frac{y}{x}\right)}\Bigg]_{y=o} \quad (3)$$

The combination of the convection heat transfer coefficient h characteristic length x and the heat conductivity of the fluid k in the form $\frac{\overline{h}x}{x}$ is called the Nusselt number. The Nusselt number is a dimension-less quantity. Assessment of equations

$$\frac{\overline{h}x}{k} = \frac{-\frac{\partial T}{\partial y}\Big]_{y=0}}{\frac{T\omega - T_\infty}{x}} = \frac{\partial\left(\frac{T_\omega - T}{T_\omega - T}\right)}{\partial\left(\frac{y}{x}\right)}\Bigg]_{y=o} \quad (4)$$

Showing the bottom of the Nusselt number can be interpreted physically as a comparison between a temperature gradient directly in contact with the surface to a reference gradient temperature. The temperature distribution for fluid flowing through a hot wall, as illustrated in full line in Figure The temperature distribution of turbulent boundary layers for fluids flowing through a flat plate, shows that the fluid temperature gradient exists only in a relatively thin layer near the surface. Now we will simplify the actual picture by substituting the actual temperature distribution with a straight dotted line. The broken line alludes to the actual temperature curve on the wall and physically shows the temperature distribution within a layer – a hypothetical fluid thick which in the case of no movement at all gives the same heat resistance as the actual boundary layer of heat flow. In this layer without movement, heat can only flow by conduction and the rate of heat transfer per unit area is:

$$\frac{q}{A} = k\,\frac{T_\omega - T_\alpha}{\delta_t} = \overline{h}\,(T_\omega - T_\alpha)$$

From the above equation it can be seen that h can be expressed as:

$$\overline{h} = \frac{k}{\delta_t}$$

And Nusselt numbers as

$$\overline{Nu} = \overline{h}\,\frac{x}{k} = \frac{x}{\delta_t}$$

The characteristics of fluid flow can be categorized as laminar flow and turbulent flow, these are distinguished based on the internal characteristics of the flow. Generally, this character depends on disturbances that occur in a flow that affect the motion of the fluid particles. In fluid flow with relatively low velocities or the fluid is very viscous, the disturbances experienced by the flow field due to vibration, boundary surface irregularities and so on, are relatively quickly muffled by the viscosity of the fluid and the flow of fluid that occurs laminar flow. Fluid flow has layers with molecular exchange that only occurs between layers bordering for these conditions[9]. Within certain limits where the flow layer moves randomly, such flow conditions are called turbulent flow. In the case of convection heat transfer, the fundamental difference between laminar and turbulent flow is that random motion in turbulent flow is much more effective at transporting mass and fluid momentum than molecular motion. Thus the irregularity of fluid flow will enlarge the convection heat transfer coefficient [10].

Reynold's number (Re) is a dimensionless number that analyzes the inertial force of fluid flow. The type of fluid flow and the frictional force that occurs against its surface will determine the Reynold Number. Fluid flow, which can be divided into three categories: Laminar, Transitional and Turbulent. To distinguish between laminar, transitional, and turbulent flows, Reynolds' number is used, which is a dimensionless number from the comparison between the inertial force and the

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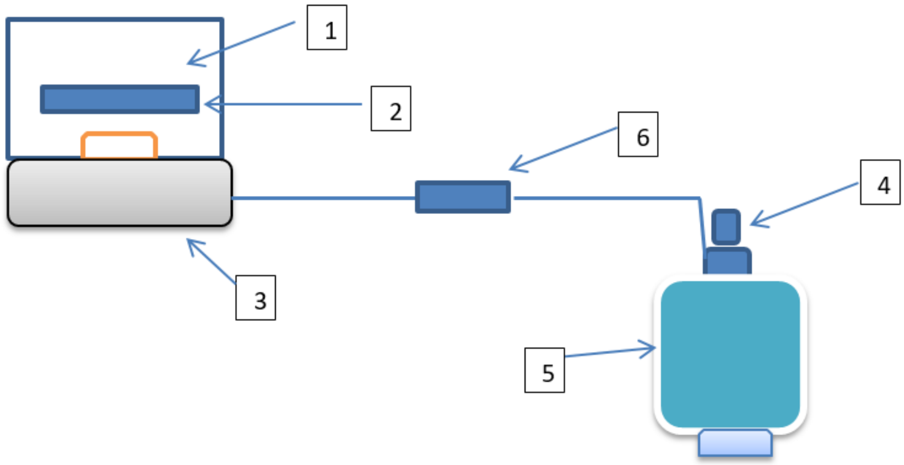
viscous force[11]. In laminar flow where fluid molecules flow following the flow lines regularly. Turbulent flow occurs when fluid molecules flow randomly without following the flow line. Transition flow is a flow that is between laminar and turbulent conditions, usually in this condition the flow changes between transient and turbulent before actually entering a full turbulent area. A small Reynolds number value (< 2100) indicates laminar flow while a large value indicates turbulent flow (> 4000). The value of the Reynolds number when the flow becomes turbulent is called the critical Reynolds number whose value varies depending on the geometric shape [12].

METHOD

The figure below illustrates a schematic diagram of the testing equipment. A stove is used to heat the water in the pot. An orifice (6) is used as a flow meter to measure the mass flow rate f LPG fuel. Orifice is calibrated to convert the measuring pressure into the capacity of the mass flow rate passing through the orifice. The efficiency of heat absorption is calculated from the ratio of heat absorbed by water to the heat of combustion of LPG gas fuel. While the heat of absorption is calculated from the difference in water heating temperature multiplied by the time and mass of water heated.



1. Pan 2. Heat collection filter 3. Gas Stove 4. Pressure Regulator 5. LPG Gas Cylinder 6. Flow Meter

Figure 1. Research schematic

In this study, the research variables consist of, independent variables, namely heat collection filters and LPG gas fuel flow capacity. While the variable is bound to the heat absorbed by water in the pot by observing differences in temperature and heating time. The test was carried out in 2 variations, namely conventional heating of the pan and using a heat collection filter base. In each of the variations mentioned above, tests were carried out with variations in LPG mass flow rate capacity from 1/4, 1/2, 3/4 to full capacity. The data collection is carried out with the following stages:

1. Turn on the stove.
2. Set the gas capacity at position ¼
3. Observe the temperature of the water in the pot, turn on the stop watch when the water reaches 40 ^{o}C.
4. Record the pressure on the orifice
5. Turn off the heat and stop the observation when the water reaches 50 ^{o}C, record the time.
6. Do as above procedure for the next variation of valve openings until the valve openings are full.

Data collection is carried out by:

1. Data collection is carried out in two stages for two independent variables, namely a stainless stell bottomless pan and a pan with a heat collection filter base.
2. In each variation, observations are made with variations in LPG mass flow rate capacity by adjusting the gas pressure regulator, from 1/4 to full capacity as the sequence in data tabulation.
3. In each condition such as the variation above, the data observed are the temperature of the water in the pan, the heating time of the water and the orifise pressure as an LPG mass flow ratemeter.

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DISCUSSION

TABLE I. THE CALCULATION RESULT DATA WITHOUT A HEAT COLLECTION FILTER

No	Gas capacity (gr/s)	Burning Heat (KJ)	Absorption Heat (KJ)	Efficiency (%)
1	0,014	167.3	128.55	76,8
2	0,025	212.5	128.55	60,49
3	0,05	250	128.55	51,4

TABLE II. THE DATA IS CALCULATED USING A HEAT COLLECTION FILTER

No	Gas capacity (gr/s)	Burning Heat (KJ)	Absorption Heat (KJ)	Efficiency (%)
1	0,014	161	128.55	79,8
2	0,025	200	128.55	64,27
3	0,05	242	128.55	53,01

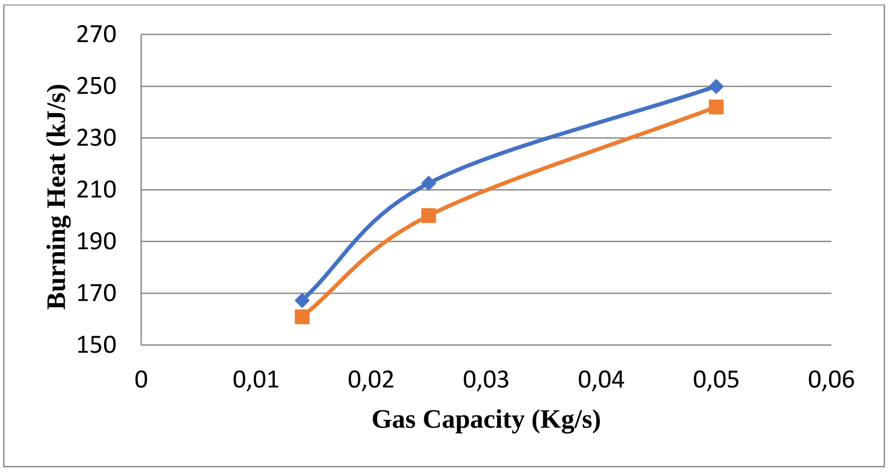

Figure 2. The relationship between LPG mass flow rate capacity to combustion heat

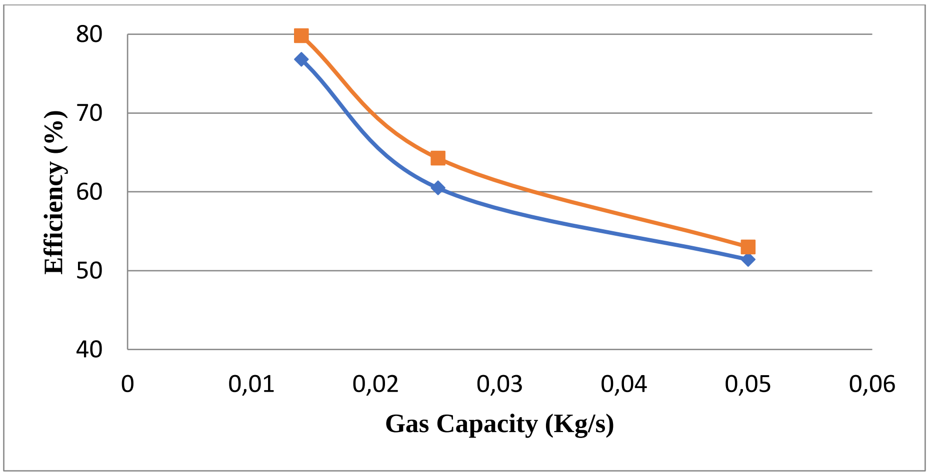

Figure 3. Graph of the relationship between LPG mass flow rate capacity to combustion heat

Data collection is carried out by heating a pot containing water weighing 3 kg from a temperature of 40ºC to 50ºC so that the heat absorbed by the pot is constant at 128.55 KJ. The size of the flame is made to vary with the valve setting, then the heating time is recorded. From the test results which

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are then depicted in graphic images show that the heat of combustion used to heat a pot containing water weighing 3 kg from a temperature of 40ºC to 50ºC increases along with the increase in LPG mass flow rate capacity. The comparison of the two curves, where without a heat collection filter (blue lines in figures 2 and 3) and with a heat collection filter (orange line in figures 2 and 3), that with a heat collection filter requires a smaller heat combustion yield or shorter absorption time under various mass flow rate capacity conditions.

While the efficiency graph shows both curves have the same trend where the results show a decrease in efficiency in increasing mass flow rate capacity. Both curves, the comparison without a heat collection filter and by using a heat collection filter, that with a heat collection filter has a higher efficiency in various conditions of LPG mass flow rate capacity.

From the graph, the results of the study show that the absorption of heat from burning LPG gas by the surface of the pan with a heat collection filter is better than without a heat collection filter under various conditions of LPG mass flow rate capacity. The increase in heat absorption efficiency on the surface of the pan is due to the resistance of the flow of combustion gases or flame flow which causes flow turbulence so that the convection coefficient increases. Likewise, the turbulence of the flame mass flow rate will reduce the fluid boundary layer on the plate wall (pan), thereby reducing the thermal boundary layer. In this phenomenon, it will reduce the heat conduction in the fluid boundary layer, on the contrary, increase the convection coefficient of the plate wall (pan surface).

This experiment also provides an overview of the phenomenon that occurs between efficiency and effectiveness in heat absorption on the plate wall (pan surface). To obtain the effectiveness of heat absorption on the plate wall (pan surface) or fast absorption time, it must increase the gas capacity or enlarge the flame while the increase in the flame will reduce the heat absorption efficiency on the plate wall.

CONCLUSION

The highest efficiency of heat absorption by the surface of the pan occurs at the smallest combustion capacity and decreases with the increase in combustion gas capacity, with the heat collection filter has better efficiency than without the heat collection filter under various conditions of combustion mass flow rate.

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