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EFFICIENCY OF HOUSEHOLD GAS STOVE BY OPTIMIZING GAP OF PAN AND STOVE COVER

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ABSTRACT

Efficiency of household gas stove has been investigated by varying the gap between pan and stove cover. The efficiency was analysed by measuring combustion energy produced by LPG, cover surface and water temperature used in cooking process. Ceramic cover was used since this cover showed the best efficiency compared to other materials in previous researches. Gap between pan and stove cover was varied in 1 mm to 7 mm with increment of 1 mm. The results showed that in certain fuel rate of 0.0125 l/s, the gap of 4 mm indicated the highest efficiency of 46.4 % because of the optimum condition was simultaneous achieved in convection and radiation heat transfer processes of the heating system.

Keywords: stove cover, efficiency, ceramic, gap.

INTRODUCTION

Data from Ministry of Energy and Mineral Resources showsthat the cost of gas is cheaper of 60% than those of using oils. Subsidy of oils from goverment in 2006 – 2008 of Rp. 105 billions is overloading to the PDB of Indonesia, so it needs to launc oils to gas conversion program start in 2007 [1,2]. However, if heating system of Conventional Gas Stove(CGS) mechanism is reobserved, there are possibilities to increase it's efficiency.

Many efforts have been performed to increase CGS's efficiency. Gohill [3], investigated a CGS by modifying and implementing some devices.The results show that efficiency aCGS increase to 66% from previous efficiency of 48%. An addition of a heat collector device or a pyramidal stove cover havealso increased by10 % or 2.8 % of the efficiency of a CGS respectively compared to a CGS without cover [4, 5].

Khan [6] investigated materials used in a CGS and its design. The experiment concludes that material and its design have a contribution to increase a CGS's efficiency. An efficiency of 4 % increases as cast iron head burner was replaced with brass head burner. A modification of flat face burner indicates adifferentiation of efficiency of 8% higher compared to flower brass burner.

An investigation by Prima [7] related with different kind of material of stove cover applied to a CGS have been performed. The results showed that stove cover of ceramic had a fine characteristic for covering heat transfer processing coming from flame into surrounding. An indication has been identified that as the gap between the stove cover and pan are closed, the efficiency of the CGS tends to decrease. Thereby, the aim of this research is to investigate the optimum gap between pan and stove cover for the best efficiency of CGS.

Efficiency

Performance of a CGS is measured using a term namely efficiency. Efficiency in this research is defined by the fraction of theheat inputcoming from combustion processwhich is converted to desired output in the form of energy which absorbed by water as shown in the equation 1 below.

$$\eta = \frac{m_w C_w \Delta T}{m_f LHV_f} x\ 100\% \qquad (1)$$

where η is efficiency, m_w is mass of water, C_w is spesific heat constant of water, ΔT is initial and end temperature differences,$m_f$is mass of fuel, $LHV_f$is lower heating value of fuel.

Definition of efficiency in equation 1 is used because of its relationship between energy losses in the heating system. The energy losses in the system is relatively complicated to identify because of the complexity of geometry of the heating system. The easiest way to identify energy losses is radiation heat transfer from the stove cover as shown in equation 2.

$$\dot{Q}_{rad} = \varepsilon \sigma A {T_s}^4 \qquad (2)$$

where $\dot{Q}_{rad}$ is radiation heat transfer, ε is emissivity of the surface,σ = 5.67 x 10^{-8} W/m^2·K^4 is the Stefan–Boltzmann constantand T_s is surface temperature.

DATA ACQUISITIONS

To obtain data related to temperature, radiation heat transfer and fuel rate, an experimental instalation was developed as ilustrated in Figure-1.

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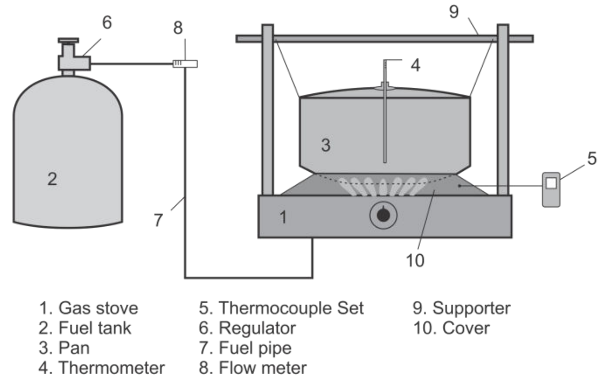

Figure-1. Ilustration of instalation.

Experimental instalation shows in Figure-1. A CGSwas a stove Quantum type QGC-101R. A standard pan with diameter of 24-cm was hanged over a supporter. Schematic illustration of optimum gap investigated in this research is seen in Figure-2.

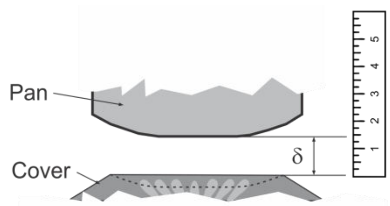

Figure-2. Schematic of gap otimation.

Mass fuel rate was measured using a flowmeter Omega FL-1501A with range spesification of 0.317-3.17 SCFM. Air temperature were measured using Alcohol thermometer type Al-30100-010 with range of scale of -10 ^oC – 110 ^oC. Surface tempeatures were obtained using k-type thermokopel which was plugged to a thermometer set KRISBOW KW06-278 Single Input Digital Thermometer.

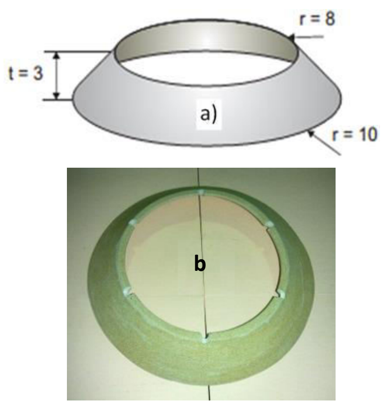

Figure-3. a) Schematic of stove cover, b) ceramic cover.

Figure-3 shows schematic illustration of stove cover and ceramic stove cover used in the experiment. Dimension of the stove cover is 10-cm for the bottom, 8-cm for the upper and height of 3 cm with 5 mm in thick. Pyramid shape is used because of practically reason.

Energy of Heating System

Due to the complexity relatedto the identification of every heat tranfer processes such as conduction and convection, energy losses can be determined and furthermore expresed in equation 3.It means that only radiation energy is explicited in the energy conservation.

$$E_c = E_{abs} + E_{r.cov} + E_l \qquad (3)$$

where $E_c$is energy from combustion process, E_{abs} is energy which is absorbed by water, $E_{r.cov}$ is radiation energy that is emmited by stove cover and E_l is energy losses instead of radiation energy.

Calculation of efficiency of the heating system is determined using definition of input and output in equation 1. Efficiency is calculated per unit time until the entire water start boiling.

EXPERIMENTAL CONDITIONS

To calculate efficiency of water heating system, experimental conditions was set up as seen in Table-1.

Table-1. Experimental Conditions.

Conditions	Value
Water mass [kg]	1
Initial temperatur of water [^{o}C]	25
End temperature of water [^{o}C]	95
C_p air [J/kg.^{o}C]	4196
Q_{LPG} [L/s]	0,0125
ρ_{LPG} [kg/L]	0,0021
$LHV_{propane}$ [MJ/kg]	46,1
LHV_{butane} [MJ/kg]	46,5
LPG Composition :	
Propane	30%
Butane	70%

Atmosfere temperature of 25 ^{o}C was assumed according to the topography of Malang City in ± 476 from sea level. The end temperature when water isstarted to boil is assumed to be 95 ^{o}C. Spesific heat constant of water is obtained in an average operational temperature of boiling system. LHV of fuel used is propotional to the composition of LPG is46.44 MJ/kg.

RESULTS AND DISCUSSIONS

Figure-4 shows a graph of efficiency per unit time in variaous gaps between pan and stove cover

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compared to a CGS without cover. It shows that efficiencies tends to low at initial heating proccess because of energy producted from combsution proccess is absorbed by any materials in the heating system including stove cover and pan. However, efficiency tend to be constant at time of 250 seconds exceeding a standard CGS (dash line).

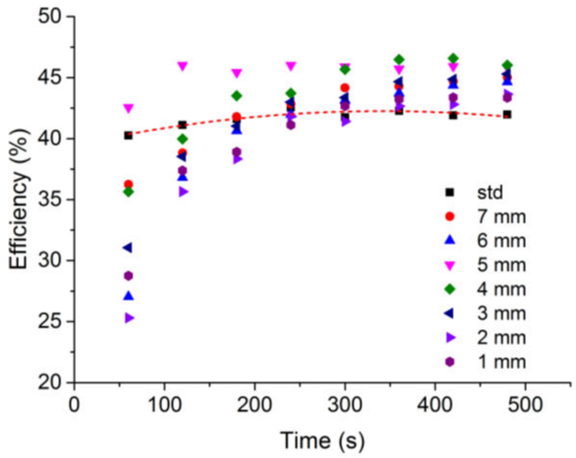

Figure-4. Heating system efficiency per unit time for gap variations.

Maximum efficiency is obtained in a gap of 4 mm in a value of 46.6%. It has a differenciation of 0.1 % from the gap of 5 mm. The efficiency indicates a time saving of 116 seconds or it is equivalent to 141.2 kJ compared to heating system in a CGS without stove cover. The highest efficiency is reached because of the optimum condition is simultaneous achieved in convection and radiation heat transfer processes of the heating system.

Polynomial line for efficiency and energy losses in various gaps is shown in figure-5. Maximum efficiency occur in gap of 4 and 5 mm. The rest gaps indicate a decreasing efficiency as shown by values of E_l that following the efficiency line but in a inverted pattern.

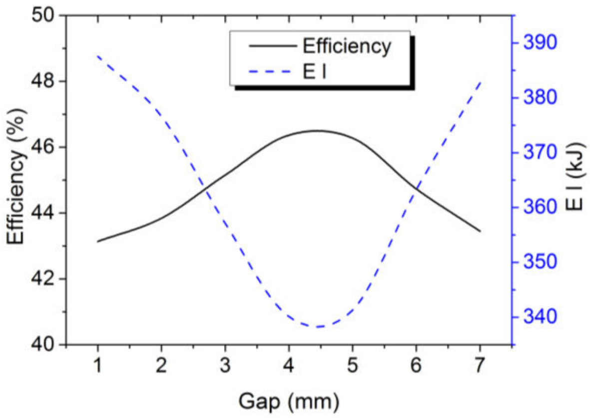

Figure-5. Polynomial line of efficiency and energy losses.

As efficiency reach a maximum value, the line of E_l shows a minimum value. E_l of 0.34 MJ is the smallest energy losses. Otherwise, maximum E_l is 0.48 MJ happened in a standard CGS.

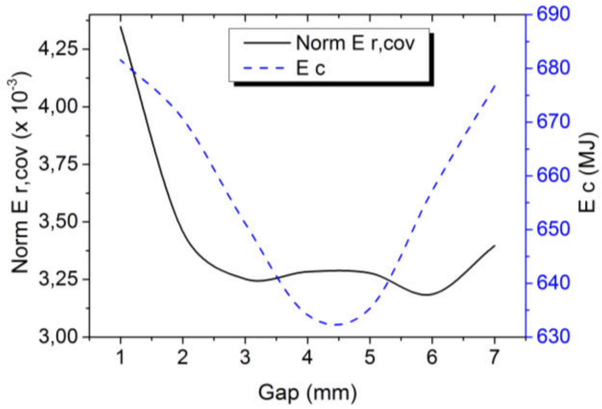

Figure-6. Norm. E $_{r,cov}$ and energy from fuel combustion.

Polynomial line has also plotted to combustion and radiation energy from the stove cover, $E_{r,cov}$as shown in Figure-6.

Term *Norm.* $E_{r,cov}$ is a normalised $E_{r,cov}$by $E_l$in various gaps. As illustrated in figure 6, gap of 1 mm shows the highest *Norm.* $E_{r,cov}$ of 4.31×10^{-3}. It shows that although radiation energy has a large value (indicated by surface temperature of 323.3°C), however energy losses coming from convection heat transfer at a gap of 1 mm is relatively small compared to other gaps. At a gap of 6 mm, *Norm.* $E_{r,cov}$ shows a smallest value of 3.17×10^{-3} although this value is not the smallest efficiency.

Energy polynomial line which is produced by combustion proccess, E_c, (dash line in the Figure-6) tend to show a decreasing trend which is contrast with efficiency line. The highest value is obtained at a gap of 1 mm meaning that in this gap needs a large energy to boil water. This phenomena is contrast with combustion energy at a gap of 4 mm.

CONCLUSIONS

In the present work, an assessment of the significance of gap between pan and stove cover in a heating system in a CGS is performend. From the disucssion it was conluded that:

- Gap between pan and cover stove affects efficienty of a CGS. In a certain fuel rate of 0.0125 L/s, maximum efficiency was obtained in a gap of 4 mm.
- The gap of 4 mm indicate the highest efficiency of 46.4 % of a CGS because of the optimum condition was simultaneous achieved in convection and radiation heat transfer processes of the heating system.

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