Improving The Efficiency Of Vesa-2 To Maximize The Energy Utilization

by Darmawi Darmawi

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Darmawi[1,2] Irwin Bizzy[1] Ellyanie[1] Jimmy D Nasution[1]

[1]Lecturer of Mechanical Engineering Department of Engineering Faculty of Sriwijaya University
Palembang - Indonesia
[2]Corresponding author email: darmawi@unsri.ac.id

Abstract: Kemplang is a crunchy traditional snack of the common people in Palembang, South Sumatra, Indonesia. Normally, it roasted on an open charcoal furnace, where the smoke, the heat and the combustion gases spread out in all directions. Vertical Energy Saver (VESA) is an equipment that has already patented created to accomodate the heat, the gas, fly ash and particulate matters from charcoal furnace used for roasting and preheating the kemplang in VESA and dispose the residual heat and gases to a place that is safe for humans breath. . VESA-2 is a VESA that already developed due to improve the effectiveness and the efficiency of equipment.. The air flew from the bottom of VESA-2 through the charcoal furnace to the top by a suction fan. VESA-2 is still developed and improved. It is completely work on the base of forced convection. Some tests are carried out to improve performance and the energy efficiency of equipment. The results of tests conducted on the base of enlargement the volume of VESA-2 is presented here. All measurements are carried out at no load. Test results show that the energy efficiency of original VESA-2 is 20.61%, the energy efficiency of VESA-2 with 30 centimeters height addition is 27.05% and the energy efficiency of VESA-2 with height addition and 28% of cross section area enlargement is 28.18%. The height addition and the cross section area enlargement are significantly increase the energy efficiency of VESA-2.

Keywords: VESA-2, suction fan, force convection, charcoal furnace, energy efficiency

1. INTRODUCTION

An appropriate equipment has been developed and already patented, called Vertical Energy Saver (VESA). VESA is used to bake kemplang which is a traditional food of people in Palembang, South Sumatra - Indonesia. Conventionally, kemplang roasting is conducted on an open charcoal furnace where the heat, the fly ash, particulate matters and combustion gases spread in all directions. This equipment is created considering the health of moms who roast the kemplang and environmental friendly for the community around the furnace (Darmawi, 2020). This system works entirely on the principle of forced convection. The air is heated by the live charcoal is passes through. The air is inhaled by a suction fan flows from the bottom of the VESA-2 upwards and exits to the atmosphere (Darmawi et al., 2020). The size of VESA is (30 x 30 x 90) cm..VESA is currently undergoing the developments which aim to improve the construction and increase the energy efficiency. The Vertical Energy Saver discussed on this occasion is referred to as the Second Generation of Vertical Energy Saver or abbreviated as VESA-2.

The heat source comes from the charcoal furnace, where the air passing through the furnace is mostly used for burning wood charcoal or coal briquettes in the furnace. The heat generated in furnace is used to roast kemplangs. The rest heat is used to dry or to preheat the kemplangs before roasted. The dryness of kemplang is necessary due to get the quality of roasted products (Darmawi et al., 2021).

From the results of previous measurements and analysis (Darmawi et al., 2021), the problem with the current prototype of VESA-2 is the exit temperature which is relatively high, which is around 76 - 81 ^{0}C. This shows that the heat content in the exhaust air is still high, so it is deemed necessary to carry out further development to make the exhaust air temperature being lowered and the thermal content in the VESA-2 is utilized more for drying and roasting process.

For this purpose, modifications were made to VESA-2 by increasing the volume of the VESA-2 room. Both of these tests is carried out under no-load conditions, where there is no roasting and no drying. So that in this way, it can be ascertained that the temperature of the exhaust air when it is loaded will be even lower due to the absorption of heat in the room for roasting and drying. So that the efficiency of the tool will increase more than at no load measurements. The presence of roasting and drying in the VESA-2 will have an impact on increasing the moisture content in the exhaust air. The addition of the room volume is intended to increase the air volume so that there is a decrease in enthalpy in the VESA-2 and at the same time lowering the exit temperature. The second way is to change the air intake method from the suction principle to the exhale principle. This second method will have implications for decreasing the velocity of the VESA-2 exit air. However, the results of the second method experiments is not reported.

2. LITERATURE REVIEW

The review is including the profile of air flow in VESA-2, the roasting process and the drying process in VESA-2.

2.a. Air speed profile in Vesa-2

This paper will discuss the temperature distribution in VESA-2 where the heat transfer process takes place completely by forced convection (Wahyu Setiawan, 2021). The airflow pattern in VESA-2 does not follow the pattern as we know it in constant cross-sectional flow (Wijiati & Widodo, 2019), because there are obstacles at three points, namely: at the air inlet position, at the 1st shelf position and at the 2nd shelf position and finally going out into the atmosphere. Figure 1 shows the variation of flow velocity at each positions on the VESA-2.

At the air intake position, the resistance occurs because the flow surface area is not as wide as the VESA-2 cross-section, where the air passage area is 56.71 cm2 and the inlet airflow velocity is 0.8 m/sec and the total intake airflow volume is equal to the incoming air from the bottom of the furnace 0.004536 m3/second plus air entering from the front door by 0.027 m3/second to 0.031536 m3/second (Darmawi et al., 2021). On the other hand, at the air exit position, the surface area of the exit door is the area of the door entering the exhaust fan, which is 0.008654625 m2, the velocity of the outgoing air flow is 3.6438 m/second and the volume of air exiting per unit time is: 0.031536 m3/second (Darmawi et al., 2021). There is a difference in the volume of intake air and outflow air of about 8% due to air entering the gaps and holes that have not been completely closed in the tool.
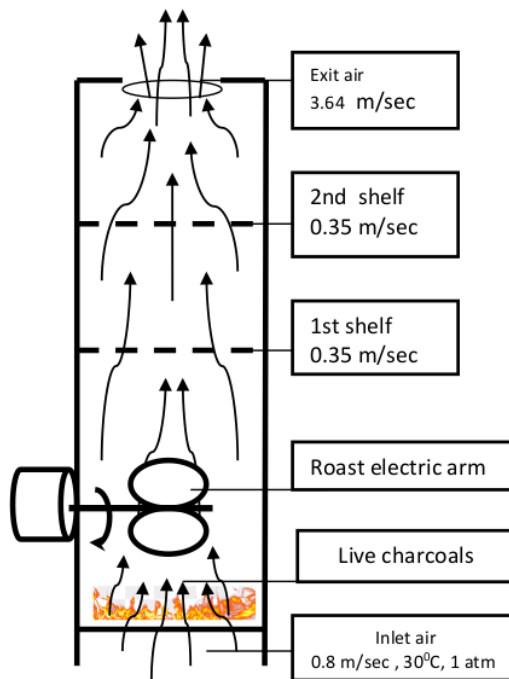
Gambar 1. Schematic image of air flow in VESA-2

2.b. Roasting process

Roasting is a way of cooking process, using an indirect and diffused heat to cook kemplang a traditional snack of Palembang people of South Sumatra Indonesia. Roasting is a dry-heat cooking method where hot air is in the viccinity of kemplang and heating it evenly on all sides at a temperature of about 150 °C (Lecreuse, 2021). The heat is generated from an open flame placed at the bottom of Vesa-2 , where the hot air is flowing from the furnace at the bottom of VESA-2 to the top by an induced draft fan. Kemplang is placed at the tip of electronic arm which turn slowly back and forth as an act of roasting. The electronic arm movement is completely simulate the manual roasting of kemplang as it traditionally done by the UMKM moms in Palembang.

2.c. Drying Process

Theoretically, the drying process requires heat energy to evaporate the water in the kemplang. Drying is a preheating process before kemplang is roasted. According to the principle of equilibrium, the water vapor pressure in the commodity to be dried is the same as the water vapor pressure of the air around the object before drying. When drying begins, hot air that flows through the surface of the kemplang will increase the pressure of water vapor on the surface of kemplang. When hot air flows through the

surface of the kemplang, mass transfer occurs from the surface of kemplang in the form of water vapor. In this way the drying process occurs followed by the entry of water pavor from the surface of the kemplang into the atmosphere air (Sary, 2017).

However, evaporation of surface water can only occur under one condition, namely that the air must not be saturated with vapor. Vapor-saturated air is air that contains so much vapor that it can no longer accept additional vapor. The drier the air, the easier it is for surface water of kemplang to evaporate. On the other hand, the more humid the air conditions, the more difficult it will be for water on the surface of commodity to evaporate (Muamar Syaidar, 2019). To find out the pressure and the temperature aspects in the drying process of food commodities, we need to understand the Hertz-Knudsen formula, or often called the Knudsen-Langmuir equation.

Irving Langmuir's basic assumption is that the number of water molecules lost due to evaporation is the same as the number of water vapor molecules in the air hitting the water surface when an equilibrium state occurs. In an equilibrium state, the rate of evaporation and the rate of condensation are the same (Heru Maruza, 2013). Formulatively written:

$$\frac{dM}{dt} = (p_v - p_p)\sqrt{\frac{m}{2\pi RT}}$$

where:
dM/s = mass flow rate (kg) over a given surface area (m-2) in one second (second,
      s-1), so the unit is kg/m2/s.
Pv = vapor pressure at a certain temperature, or boiling point pressure at temperature
      specified, in units of pascals (pa).
Pp = vapor partial pressure of the substance in the gas mixture, for example the vapor pressure of
      water in air at a certain temperature, in units of pascals (pa).
m = molecular weight of water (0.01801528 kg/mol).
R = ideal gas constant or Mendeleev's constant = 8.314 Joules/(mol Kelvin).

From the above formula it can be understood that if the vapor pressure (Pv) is greater than the partial pressure (Pp) of water vapor in the commodity, evaporation will occur. On the other hand, if the partial pressure of water vapor in the commodity (Pp) is greater than the vapor pressure (Pv), condensation will occur (Heru Maruza, 2013).

The weakness of the Irvin-Langmuir formula above is that the drying rate is only viewed from the aspect of pressure and temperature. Meanwhile, in the force convection process, there are other factors that are no less important, namely: the speed of the drying air flow, the temperature of the drying air and the relative humidity of the drying air (Dina et al., 2019)(Henderson & R.L. Perry, 2009).

3. MATERIAL AND METHOD

Two method of experiments were carried out, basically base on the volume of the VESA-2 enlargement. Diagrammatically, it can be sorted as shows in figure 2.

To calculate the efficiency and effectiveness of equipment, tests and measurements are carried out at no load. This means that no roasting and drying takes place in the VESA-2. This is done to measure the performance of the VESA-2 at the worst performance, where all heat is considered unused.

$$q_{conv} = \dot{m}c_p(T_{m,o} - T_{m,i})$$

where Tm denotes the average air temperature and the subscription i and o denote inlet and outlet air condition respectively. It is important to note that the above equation is a general expression of energy balance in VESA-2 (Sinaga, 2019). Cp is a contant of air heat capacity, 1.005 kJ/kg.K at room temperature (G.F.C. Rogers & Y.R. Mayhew, 1996).

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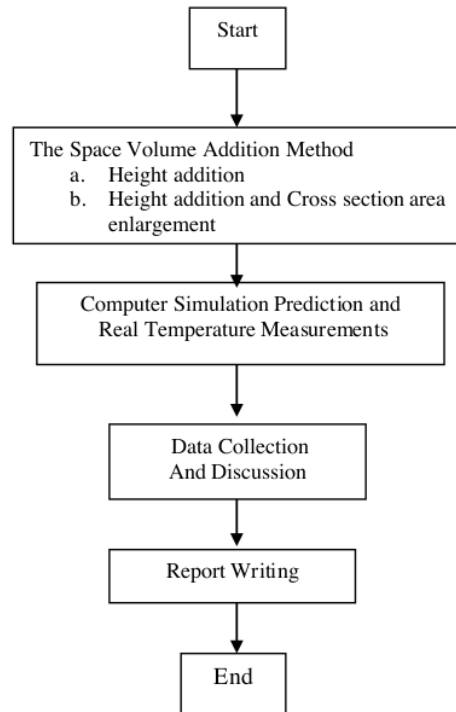
Figure2. Flowchart of the experiments

4. COMPUTER TEMPERATURE DISTRIBUTION PREDICTIONS AND REAL TEMPERATURE MEASUREMENTS

4.a. Computer Temperature Distribution Predictions

Prediction by computer simulation have been carried out using the flow simulation program as a technical reference. Assuming the fluid is compressible. Solid particles such as particulate matters are not considered specifically. The flows are laminar and steady. Temperatur distribution in VESA-2 are as follows:
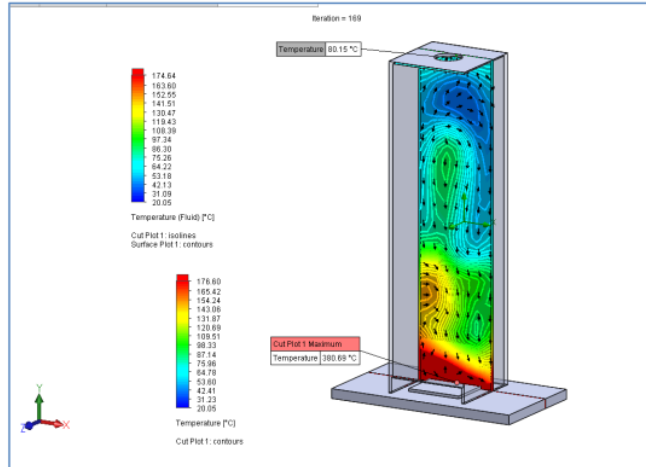
Figure 3. Temperature distribution at VESA-2 where the temperature at live charcoal is of 380.9 ºC and exit temperature is 80.15 ºC
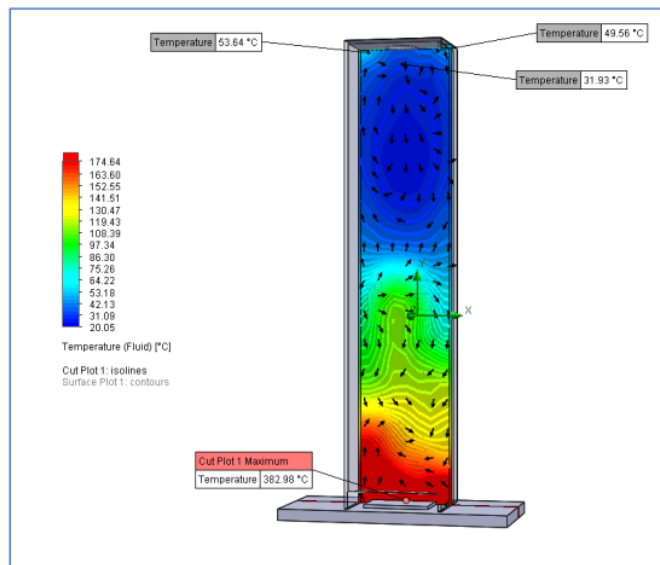

Figure 4. Vesa-2 with height addition, where the live charcoal temperature is 382.98 ºC and exit temperature is 53.84 ºC
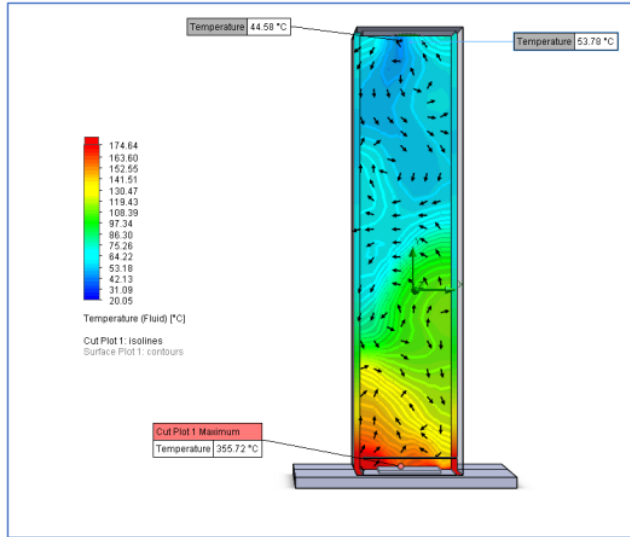
Figure 5. Vesa-2 with height addition and 28% cross section area enlargement, where the live charcoal temperature is 355.72 ºC and exit temperature is 44.58 ºC

4.b. Average Actual Temperature Distribution Measurements in VESA-2

Real measurements are already carried out at VESA-2. In this paper we present three modification of VESA-2. The three of them are Vesa-2 with no size modification is called Original Vesa-2, Vesa 2 with 30 cm height addition, and Vesa-2 with 30 cm height addition and 28% cross section area enlargement. The average actual temmperature measurements of related VESA-2 as presented in Table 1.

Tabel 1. Average actual temperature in VESA-2

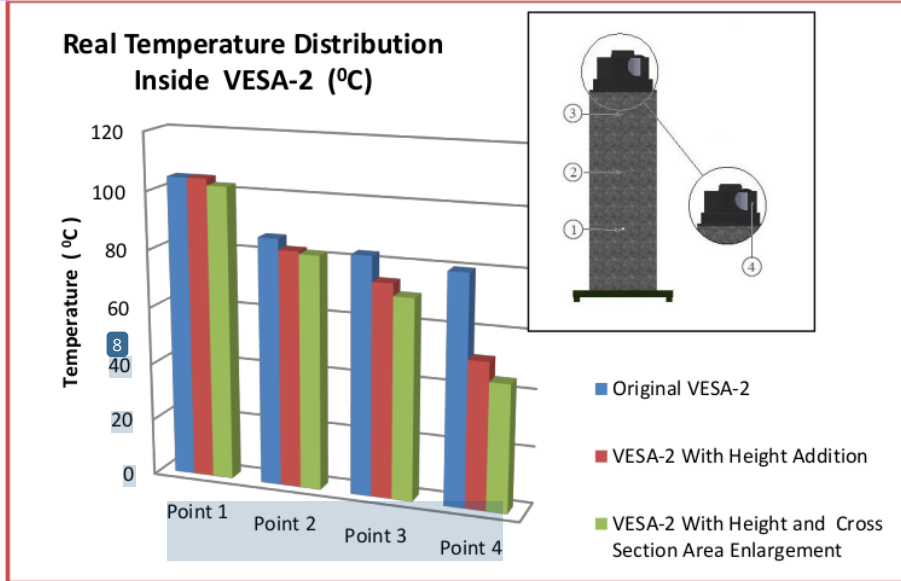|	Original Vesa-2	Vesa-2 With Height Addition (ºC)	Vesa-2 With Height and Cross Section Area Enlargement (ºC)
Point 1	104.57	104,6	102.3
Point 2	86,14	82,4	81.5
Point 3	82,85	74.3	70,1
Point 4	79,91	51.3	44,6

Figure 6. Real temperature of VESA-2 at varying size modification.

5. THERMAL ENERGY EFFICIENCY OF MODIFIED VESA-2

Thermal energy efficiency of VESA-2 at no load operation. Tthis is the worst efficiency VESA-2 would make. The thermal efficiency of VESA-2 is defined as the energy out of VESA-2 persecond divided by the energy produced by the live charcoal at the bottom of VESA-2 persecond.

Tabel 2. Thermal energy efficiency of VESA-2

	$\dot{m}_{out}$ (Kg/sec)	$\dot{m}_{in}$ (Kg/sec)	Q_{in} (Kj/sec)	Q_{out} (Kj/sec)	η_{th} (%)
Original VESA-2	0,0378432	0.03214	14.37418	11.41058	20.61
VESA-2 with Height Addition	0.0378432	0.03214	14.37532	10.48554	27.05
VESA-2 with Height Addition and Cross Section Area Enlargement	0,0378432	0.03214	14.28776	10.26030	28.18

The calculation is based on the quantity of air intake and exit VESA-2 as measured previously. Cp = 1,005 (Kj/Kg.K). Air density is 1.2 kg/m^3 (John Twidell & Tony Weir, 2006).

6. DISCUSSION

Comparison between the computer temperature prediction and the real temperature measurements are tend to similar or a tiny different. It is because the dynamic flow of air inside VESA-2 and the dynamic fluctuation of energy supply to VESA-2 regarding the quantity and the quality of charcoal burnt at the furnace. Charcoal is a hydroscopic matter, the higher the moisture contents in the charcoal, the lower the thermal energy produced in furnace. The charcoal water contents can not accurately detected or measured, so it is considered the same.

From the data analyzing and the results presented above, we can see the improvements of VESA-2 energy efficiency. The energy efficiency tend to increase by the addition VESA-2 body volume. This body volume is enlarged by VESA-2 size modification. The measurements show clearly that the height addition of VESA-2 and the cross section area enlargement significantly lowering the air exit temperature of VESA-2. This phenomenon indicating that the height addition or the cross section area enlargement is encourage the better energy accomodation inside VESA-2. It means, the more energy will be utilized. The lowest energy efficiency is found at original VESA-2 where no size modification was made. It is mainly because there is a window at the bottom of the equipment where the air could enter. This window is used to roast the kemplang manually. A part of air is partially not absorb the heat from the furnace because rapidly inhaled by the top fan. This is the one of the causes of low efficiency. Modified VESA-2 has better efficiency because the size of the window already

reduced, even at the next experiments VESA-2 has no more window. The manual roasting act is already replaced by an electronic arm. It is hoped that a better thermal efficiency will got.

7. CONCLUSIONS

From the data found and the above analysis we can conclude the followings:

a. The volume enlargement will maximize the heat accomodated and will increase the heat utilization of VESA-2

b. The height addition significantly increase the thermal energy efficiency, meanwhile, the cross section area enlargement of VESA-2 support slightly.

c. The combination between height addition and cross section area enlargements is considered as a wise decision to downgrade the heat loss and increase the thermal efficiency of VESA-2.

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Authors:

First author – Darmawi, Mechanical Engineering of Faculty of Engineering of Universitas Sriwijaya Indonesia, darmawi@unsri.ac.id.

Second author – Irwin Bizzy, Mechanical Engineering of Faculty of Engineering of Universitas Sriwijaya Indonesia, irwinbizzy@unsri.ac.id

Third author – Ellyanie, , Mechanical Engineering of Faculty of Engineering of Universitas Sriwijaya Indonesia, ellyanie@unsri.ac.id

Fourth author – Jimmy D Nasution, , Mechanical Engineering of Faculty of Engineering of Universitas Sriwijaya Indonesia, jimmynasution@unsri.ac.id

Corresponding author – Darmawi, lecturer of Mechanical Engineering Department of Engineering Faculty of Universitas Sriwijaya – Indonesia. Phone: +628127886884

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