Modelling the Temperature and Efficiency of a Waste Electrical Power Generator Using the Impact Wrench to Replace a Turbine

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Abstract. The objective of the research is to obtain the maximum temperature in the boiler work space and calculate the efficiency of a simple type of waste treatment system. The modelling using several secondary data is the method in this study. Researchers are using impact wrench, where the tool works based on pressure. Boiler pressure is \(8 \times 10^5\) N/m\(^2\), volume 0.05 m\(^3\) while the volume of impact is \(7 \times 10^{-4}\) m\(^3\). The temperature first 0\(^o\)C will increase to temperatures in the search. Exterior expansion work is \(4.17 \times 10^4\) J. The temperatures of fluid for mass 50 g is 396\(^o\)C. The Spe...
input. Total efficiency $\eta$ is the ratio of output divided by input times 100%. Input is the heat of waste property while the output is the energy in the boiler.

2. Method
The method used in this research is a review of the literature using a computer as computing tool (computation) to complete the calculation of the temperature and efficiency of the GEPW. Numerical computation includes: (1) Calculation of volume and temperature change in the initial work system (boiler) to obtain the final temperature. (2) Electrical power of calculation. (3) Efficiency of computation (performance) based on the output work, namely the boiler and input work of incinerator.

The gasses of mass $nM$, volume $V$ and $M$ molecular weight (gram/mol) and $n$ is the number of moles, density mass $\rho$ is $nM/V$. Reduces $\rho$ (reduces $n$), put gas in the larger containers (enlarge $V$). For the low density, thermodynamic variables $P$, $V$, and $T$ follows the ideal concept gas. Mass $nM$ gas in a state of thermal equilibrium can be measures pressure $P$, temperature $T$ and volume $V$. For a low density then (1) a constant temperature, the pressure is inversely proportional to the volume (Boyle’s law). (2) The constant pressure, volume directly proportional to the temperature (law of Charles and Gay-Lussac).

$$\frac{pV}{T} = \text{constant} \quad (1)$$

Constants related to the gas masses $H_2O$ [6]. The volume occupied by a gas at a given pressure and temperature is proportional to its mass. For the constants of the equation must therefore be proportional to the mass of the gas. Constant $nR$ with $n$ is the number of moles of gas. For a low density, $R$ have the same value for all of gases, namely 8.314 J/mol.K, then

$$pV = nRT \quad (2)$$

The real gas will approach the properties of the ideal gas of abstraction so low density. Equation (2) is called the ideal gas state equation. Incompressible flow which have cross section $A_1$ going up to $A_2$ with the altitude $y_2$. The narrow pipe part is $P_1$ and $v_1$ and the width part $P_2$ and $v_2$.

![Figure 1. The Fluid Portion Passes through the Pipe Portion from the Position Shown in (a) to the Position Shown in (b)](image)

The forces are $P_1A_1$, $P_2A_2$ and gravity. The work $W$ : (1) $P_1A_1\Delta l_1$ . (2) $-P_2A_2\Delta l_2$. Negative, which means the positive work done by the system. (3) Work done by gravity is $-mg(y_2 - y_1)$. It is also negative because the system does the work against the force of gravity. Work done on the system

$$W = P_1A_1\Delta l_1 - P_2A_2\Delta l_2 - mg(y_2 - y_1) \quad (3)$$

Fluid volume $A_1\Delta l_1 (= A_2\Delta l_2)$ can write liquid $m/\rho$, where $\rho$ is the density of the fluid (constant). Element fluid have the same mass so that $A_1\Delta l_1 = A_2\Delta l_2$ in the fluid considered is not compressed. With this hypothesis then

$$W = (P_1 - P_2)(m/\rho) - mg(y_2 - y_1) \quad (4)$$

The changes of the kinetic energy of the fluid element are

$$\Delta K = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 \quad (5)$$

From the work power theorem, we get $W = \Delta K$ or

$$(P_1 - P_2)(m/\rho) - mg(y_2 - y_1) = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 \quad (6)$$
Thus, the working relationship with pressures is listed in equation (6).

Based on the Faraday concept [7] namely

\[ \varepsilon = -\frac{d\phi_B}{dt} \]  \hspace{1cm} (7)

where \( \phi_B \) is the magnetic field flux. A minus sign means that there is an action from the outside. Lenz’s law states that the applied force must be greater to combat the poles of the permanent magnet [8]. The formula to calculate more quantitatively the induction EMF [9], namely

\[ \varepsilon = Blv \] \hspace{1cm} (8)

\( B \) is the strength of the magnetic field and \( l \) the length of the wire used. If the number of coil is many and the speed is high, the induction EMF will be even greater.

Angular acceleration is defined as the change in angular velocity \( \Delta \omega \) divided by the time change.

\[ \alpha = \frac{\Delta \omega}{\Delta t} \] \hspace{1cm} (10)

The radial component \( (\vec{a}_r) \) is the centripetal acceleration \( (|\vec{a}_r| = |v_r^2/r| = |\omega^2 r|) \) that leads to the center of the circle. Relationship between the angular velocity \( (\omega) \) and the rotation frequency \( (f) \), where frequency is the number of revolutions per second. The frequency is the number of revolutions per minute \( (rpm = revolution\ per\ minute) \).

One circle is relationship with the angle \( 2\pi \)radian of rotation as well \( 1 \) putaran/s = \( 2\pi \) rad/s [6]. If the force is applied, the angle of acceleration of an object is proportional to the size of the hand and also proportional to the distance from the axis to the point where the force works. The product is called torque. The units is \( Nm \) [10].

\[ F = m \omega \] \hspace{1cm} (11)

while torque \( \tau \) to \( \theta = 90^\circ \) are

\[ \tau = rF = mr \omega \] \hspace{1cm} (12)

The magnitude \( mr^2 \) indicates inertia moment with the units \( kgm^2 \). Rigid object in rotation, for all of the particles of an object linked with

\[ \tau = \left( \sum m \right) \omega \] \hspace{1cm} (13)

The speed impact \( \omega \) is 7000 rpm or 733 m/dt, and torque 500 Nm is therefore the power are

\[ W = \tau \times \omega = 500 \times 733 = 366.519 \text{ joule} \] \hspace{1cm} (14)

The maximum impact energy is 366.519 joule. The energy in the boiler is 40.000 joule, so the impact can accommodate the work done.

The initial equation used is equation (1). When it is heated, there will be an increase in the temperature in the boiler and an increase in pressure. Following equation (1) then

\[ \frac{PV_{initial}}{T_{initial}} = \frac{PV_{final}}{T_{final}} \] \hspace{1cm} (15)

If the temperature increases, the pressure increases as the temperature decreases. When the boiler is heated, the pressure is higher than the external pressure, the gas will be released in the turbine. Researchers are replacing impact turbines (modelling), where this tool operates relying on the pressure of a moving fluid.
The maximum pressure that a boiler can have is $8 \times 10^5 \text{N/m}^2$ (technical data sheet of the boiler tube). The volume of the boiler is 0.05 m$^3$ while the impact volume is $7.1 \times 10^{-4}$ m$^3$. Using equation Bernoulli (6), then

$$P_{\text{boiler}} V_{\text{boiler}} = P_{\text{impact}} V_{\text{impact}}$$

(16)

Energy belonging to the system

$$U = P_{\text{boiler}} V_{\text{boiler}} = (8 \times 10^5 \text{N/m}^2)(0.05 \text{m}^3) = 4 \times 10^4 \text{J}$$

(17)

The sizes energy 40,000 joule is the energy held by the boiler.
Initial input i.e. the initial pressure $P_{\text{initial}}$ of $10^5$ N/m$^2$. The input water with mass $m_1$, $m_2$, $m_3$, $m_4$ and $m_5$. By entering the density of the water 1000 kg/m$^3$, the volume of each mass above can be searched. Changes in volume and temperature during incinerator heating will be evaluated in the calculation to achieve the desired temperature. The temperature is the temperature at the set to reach the works 40,000 joule. It is assumed that the initial mass of water 50 g and the initial volume $5 \times 10^{-5}$ m$^3$ will grow to reach the volume $5 \times 10^{-2}$ m$^3$ of the space thereafter. Initially temperature 0$^\circ$C will increases until the temperature that we are looking for. The external expansion work that required to increase the gas from the initial volume to a certain volume which sizes $P(V_v - V_l)$. The internal energy added to the system is

$$\Delta U = W = mc\Delta T - P(V_v - V_l)$$

By entering the body of water, the heat of the water type, the expansion performance outside the temperature and the final temperature are obtained. The impact used is an impact with specific pressure and speed specifications. Impact turns the generator. Enter the speed and speed of impact for the power to be known. For the first second, the energy (heat) for waste with mass and can be calculated, see Figure 3.

Efficiency $\eta$ according to the work of boiler and incinerator (flow chart Figure 4). The total efficiency is the ratio between the output energy of the boiler divided by the input energy of the incinerator times 100\%.

$$\eta_{\text{tot}} = \frac{W_{\text{output}}}{W_{\text{input}}} \times 100 \%$$

The input energy is the energy (heat) belonging to the waste while the output energy is the energy which available in the boiler where the amount is power $W_1$ and $W_2$. Using the equation (19), the efficiency of waste mass $m_1$ and $m_2$ proportion with the time in seconds can be determined.

3. Results and Discussion

The initial pressure of $10^5$ N/m$^2$. For the first up to the fifth fluid mass at 50 g, 100 g, 150 g, 200 g and 250 g. The volume of each mass are $5 \times 10^{-5}$ m$^3$, $4 \times 10^{-5}$ m$^3$, $6 \times 10^{-5}$ m$^3$, $10^{-4}$ m$^3$, and $2.5 \times 10^{-4}$ m$^3$. Suppose the initial mass 50 g and the volume $5 \times 10^{-5}$ m$^3$ will swell with meeting space with the final volume $5 \times 10^{-2}$ m$^3$. The temperature will increase to the desired temperature

$$W = P(V_v - V_l) = 8,34.10^5(5.10^{-2} - 5.10^{-5}) = 4.17 \times 10^4 \text{ J}$$

The required extension works are as important as $4.17 \times 10^4 \text{ J}$

$$\Delta U = mc\Delta T - P(V_v - V_l)$$

By entering the mass of water $5 \times 10^{-2}$ kg, the water specific heat 4200 J/kgK, the expansion work external $4.17 \times 10^4 \text{ J}$ obtains the final temperature.

![Figure 4. Flow Chart to Find Efficiency per Waste Mass](image-url)
The Graph relation between mass, temperature and the energy of the fluid in the boiler (Figure 5).

The temperature of the fluid whose mass 50 g is 396°C, the mass 100 g is 105°C, the mass 150 g is 132°C, the mass 200 g is 99°C and the mass 250 g is 80°C. The greater becomes mass of the water which given then temperature required becomes lower. Thus, the use of burnt waste in the incinerator room also decreases. Impact used with specifications pressure $6 \times 10^5$ N/m$^2$, maximum speed is 7000 rpm and maximum torque 500 Nm. Equation (8) if the linear speed becomes higher which associated with the rotational speed, the induced EMF ($\varepsilon$) becomes larger. The impact velocity is 7000 rpm converted to unity m/dt becomes 733 m/dt. The torque is 500 Nm thereby the power are

$$ W = \tau \times \omega = 500 \times 733 = 366519 \text{ joule} \quad (22) $$

If the waste is mass 10 kg and has a heating value (HHV) 2500 kcal/kg [8], the heat for 10 kg is

Figure 5. The Relationship Graph Between Mass, Temperature and Power of a Fluid

Figure 6. The Graph which Comparing Power and Time for Waste with a Mass of 5 kg and 10 kg
\[ Q = m \cdot HHV = (10 \text{ kg}) \cdot (2500 \text{ kcal/kg}) = 25,000,000 \text{ kcal} = 6.1 \times 10^6 \text{ J} \]  

(23)

The relation of work \( W \) to heat \( Q \) is \( W = Q \). The connection power \( P \) with the heat \( Q \) is as follows \( Q = P \cdot t \). For per second the work done can be written

\[ P = \frac{6 \times 10^6 \text{ J}}{1 \text{ s}} = 6 \times 10^6 \text{ W} \]  

(24)

\( W \) in itself is a unit of power. In time 1 hour = 3600 second then \( P = 1667 \text{ W} \). In time 10 hour = 36000 second then \( P = 167 \text{ W} \). For the first second (see Figure 7) then energy of the waste with mass 5 kg and 10 kg are \( 1.25 \times 10^7 \text{ J} \) and \( 2.5 \times 10^7 \text{ J} \). Linearly decreases up to five seconds when the calorie is about to the mass 5 kg and 10 kg are \( 2.5 \times 10^6 \text{ J} \) and \( 5 \times 10^6 \text{ J} \).

In the graph, it seems to be an exponential function, but linear, with a very large density. At the seconds of 125, the waste with the mass 5 kg and 10 kg has a heat of \( 10^5 \text{ J} \) and \( 2 \times 10^5 \text{ J} \). The amount of electrical energy depends on the storage space of the accumulator. Researchers use a car battery 70 AH, the maximum electrical power is 840 WH or 3024 kW. Input energy is the heat produced by the waste, while the output energy is the energy 40,000 J available in the boiler where it is located. Using the equation (20) then efficiency of the mass waste \( m_1 \) and \( m_2 \) proportional to the time in seconds viewed on the graph in the Figure 8 below. From the graph shows that the waste of mass 5 kg have efficiency to higher compared than the mass 10 kg but have decreased significantly. The waste with the mass 10 kg also decreased but not significantly with that 5 kg.

\[ \text{Figure 7. The Graph which Comparing Power and Time for Waste with the Masses of 5kg and 10kg} \]
4. Conclusion
The changes in volume and temperature during the heating of the incinerator are examined in the calculation in order to obtain the desired temperature. Larger mass of the water that given then the required temperature becomes lower. Thus, the use of burnt waste in the incinerator room also decreases. The graph shows that mass waste 5 kg has a higher efficiency than mass waste 10 kg but has been around decreased significantly. On the otherhand waste of the mass 10 kg has also decreased but not significantly with that 5 kg.

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