Exhaust heat utilization for distillation of water

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ABSTRACT

The current worldwide trends of increasing energy demand in the transportation sector are one of the many segments that are responsible for the growing share of fossil fuel usage and indirectly contribute to the release of harmful greenhouse gas emissions. In addition to contributing to the goal of saving energy, utilization of waste heat is also an important source of cost savings. It’s the fact that almost 70% of the energy released from the fuel by an engine is lost, mostly in the form of heat. There is approximate 25–30% of the energy engines generate dissipating in the form of exhaust loss energy. Even high-efficiency modern engines have only 25 ~ 50% thermal efficiency and the remaining 50 ~ 85% of low heating values of the fuel are dissipating into the environment as a form of heat transfer and exhaust gas enthalpy. If the exhaust gas enters into surroundings directly, it will not only waste energy but also damage the environment. So, the effort has been made here to recover the waste heat from the static Internal Combustion engine to get distilled water.

Keywords—Exhaust, Heat, Engine, Water, Distillation

1. INTRODUCTION

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then “dumped” into the environment even though it could still be reused for some useful and economic purpose. During engine run time, there are four sources of usable waste heat from a reciprocating engine: exhaust gas, engine jacket cooling water, lube oil cooling water, and turbocharger cooling are dissipated to the atmosphere.

The waste heat is generally classified into two types:

1. High-grade waste heat
2. Low-grade waste heat

The heat carried away at a temperature higher than 300°C is considered as high-grade waste heat and heat carried away below 300°C is classified as low-grade waste heat. All this waste heat appears as low-temperature heat. Because of the growing quantities of waste heat discharge and increasing ecological concern with energy consumption, energy utilization and thermal discharge problems have stimulated an examination of the method, for using energy presently wasted to the environment. The single largest amount of unused heat from the engine is the exhaust heat, which contains about 30% of the fuel energy. It is evident that exhaust gases come out from the exhaust port at a very high temperature, it has been seen that in diesel engines exhaust emission are at the high temperature of 250°C to 600°C (approx.) with high quality and quantity.

Table 1: Various engine and there output

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Power Output (kW)</th>
<th>Waste Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small air cooled diesel engine</td>
<td>35</td>
<td>30-40% of energy waste loss from IC engines</td>
</tr>
<tr>
<td>Water air cooled engine</td>
<td>35-150</td>
<td></td>
</tr>
<tr>
<td>Earth moving machineries</td>
<td>520-720</td>
<td></td>
</tr>
<tr>
<td>Marine applications</td>
<td>150-220</td>
<td></td>
</tr>
<tr>
<td>Trucks and road engines</td>
<td>220</td>
<td></td>
</tr>
</tbody>
</table>

2. LITERATURE SURVEY

The literature survey of exhaust heat utilization for distillation of water explains briefly about the existing systems and problems that are present in those systems.

Several innovative cooling and exhaust heat recovery systems have been introduced to reduce cooling loss and regenerate the power by recovering the waste heat.

Hatazawa and Stabler [1] stated that the waste heat produced from thermal combustion process generated by engine could get as high as 30–40% which is lost to the environment through an exhaust pipe.

S N Srinivasa [2] have attempted to explore the various possibilities of waste heat energy recovery methods in conventional commercial two wheeler and four wheelers.
Kruiswyk [3] developed components, technologies, and methods to recover energy lost in the exhaust processes of an internal combustion engine and utilize that energy to improve engine thermal efficiency by 10%.

Saidu [4] have studied the different technologies to recover the heat wasted from the exhaust gas of IC engines and concluded that there is a huge potential for extracting the waste heat from the exhaust gas of IC engines.

Rubaiyat [5] conducted experiments to measure the exhaust waste heat available from a 60 kW automobile engine and a computer simulation was carried out to improve the design of the heat exchanger. The proposed heat exchanger can produce 10%, 9%, and 8% additional power by using water, ammonia, and HFC-134a as the working fluids respectively.


Jiricek [7] designed and modelled a new steam sterilization system for proper sterilization and cleaning of medical equipment for field hospitals using waste engine heat from the exhaust system of a diesel generator and decreases the reliance on electricity of traditional sterilization methods.

Aly [8] have studied the comprehensive applications of exhaust gas recycling and circulating cooling water WH recovery of the internal combustion engine. This amounts to about 15% of the base engine output.

Stephanie [9] introduced Waste heat recovery (WHR) systems that have an interesting way to improve the efficiency of internal combustion engines and reduce their fuel consumption for a given mechanical output.

Pandiyarajan [10] have studied experimentally how to recover exhaust gas WH of the automobile and designed a finned tube heat exchanger and a heat storage system.

Agnew [11] have calculated the rate of WH recovery for supercharged engine exhaust gas.

3. EQUIPMENT FABRICATION

Our project is for distillation of water utilizing the heat of the exhaust gas. The waste heat is utilized to heat the water in a tank by passing the exhaust pipe with some protective enclosure across the water tank. The steam formed can be condensed and the distilled water can be stored which could be used in the industry. The comparison has been made among these utilization methods to select the most suitable method. The methodology is as shown below:

3.1 Components required

The components required for the exhaust heat utilization for distillation of water are listed below:

- Internal Combustion Engine
- Heat Exchanger
- Condenser
- Copper pipe
- Valves
- Tank

3.2 Design of heat exchanger

To produce distilled water the water must be heated above 273 K and then cooled in a condenser to obtain distilled water. Therefore design methodology consists of:

1. Design of heat exchanger
2. Design of condenser
The quantity of heat required to heat water from 303 K to 383 K is calculated as follows:

**Consider one Kg of water:**
The inlet temperature of the water be T= 303 K
The outlet temperature of steam be T= 383 K

**This required heat consists of:**
- Sensible heat to raise the temperature of water from 303-373 K.
- Latent heat to vaporise the water
- The sensible heat required to raise the temperature of steam from 373-383K

**Heat required is:**

\[
Q = m \times C_p \times (T_w - T_1)
\]

Where,
- \(Q\) = Heat required in Joules
- \(M\) = Mass of water = 1Kg
- \(T_1\) = Inlet temperature of water = 303K
- \(T_w\) = Temperature of water at boiling point = 373K

\[
\therefore Q_1 = 1 \times 4180 \times (100 - 30) = 292600 J/kg
\]

= 292.6 KJ/Kg

\(= Q_1 - \) (1)

Latent heat of water = 2400 KJ/Kg

\(= Q_2 - \) (2)

Sensible heat required to raise the temperature of steam from 373K to 383K:

\[
Q_3 = m \times C_p \times (T_2 - T_w)
\]

\[
Q_3 = 1 \times 2000 \times (110 - 100) = 20000 J/kg
\]

= 20 KJ/Kg - (3)

Total Heat required = (1) + (2) + (3)

\[
= 292.6 + 2400 + 20 KJ/Kg
\]

\[
= 2712.6 KJ/Kg
\]

**Calculation of Length of Heat exchanger**

\[
Q = UA \Delta T
\]

Where,
- \(Q\) = Required heat to be transferred
- \(U\) = Overall heat transfer coefficient
- \(\Delta T\) = Temperature

\[
310.86 = 100 \times \pi \times d \times 70 \times L
\]

\[
L = \frac{310.86}{100 \times 0.06} = 0.255m
\]

Considering the space for steam flow and welding, \(L=0.3m\)

**4. FABRICATION**
5. EXPERIMENTATION
The performance test is conducted for the following parameter of the engine.

- Engine speed.
- Thrust
- Torque
- Power
- Efficiency

Exhaust heat utilization for distillation of water is a waste heat recovery system which is based on the principle of organic rankine cycle. The system consists of an IC engine, heat exchanger and condenser.

![Experimental setup](image)

The various components are fabricated as shown in the figure 2.

6. EXPERIMENTAL RESULTS AND CALCULATIONS

6.1 Calculation of net heat utilized
The heat exchanger was fixed in place of the exhaust pipe and the joining was made leak proof. Water was filled in the outer tube and the engine was started.

After about 30 minutes the first drop of distilled water was obtained. For one hour the amount of distilled water collected was 200ml.

At idle conditions of the engine the temperatures of the various process were recorded:

- Inlet temperature of exhaust gases = $T_{hi} = 433K$
- Outlet Temperature of exhaust gases = $T_{ho} = 382K$
- Inlet temperature of water = $T_{ci} = 303K$
- Outlet temperature of steam = $T_{co} = 374K$
- Mass flow rate of exhaust gases = $M_h = 7.68 \times 10^{-3}$ Kg/s
- Mass flow rate of steam = $M_c = 0.2$ kg/hr = $5.55 \times 10^{-5}$ Kg/s
- Specific heat of exhaust gases = 1013 KJ/Kg K
- Specific heat of water = 4170 KJ/Kg K

\[ Q_g = M_h C_p (T_{hi} - T_{ho}) \]
\[ = 7.68 \times 10^{-3} \times 1013 \times (160-109) \]
\[ = 396.77 \text{ J/s} \]

6.2 Heat supplied by exhaust gases

6.3 Heat taken away by water
This consists of three parts:

- Sensible heat to raise the water from 303K to 373K
- Latent heat to convert water to steam at 373K
- Sensible heat to raise the temperature of steam from 373 to 374K
Sensible heat $Q_s = M c p c (T_{co} - T_{ci})$

$$= 5.55 \times 10^{-5} \times 4180 \times (373 - 303)$$

$$= 16.23 \text{ J/s}$$

Latent heat of Vapourisation $Q_v$

$$= 5.55 \times 10^{-5} \times 2100 \times 10^3$$

$$= 116.55 \text{ J/s}$$

Heat for raising the steam from 373 to 374K

$$= 5.55 \times 10^{-5} \times 2000 \times 10^3$$

$$= 111 \text{ J/s}$$

The total amount of heat utilised $Q_t = Q_s + Q_v + Q_{t1}$

$$= 116.55 + 16.23 + 111$$

$$= 232.78 \text{ J/s}$$

Percentage heat utilization from exhaust gases

$$= \frac{Q_t}{Q_g} \times 100$$

$$= \frac{232.78}{396.77} \times 100$$

$$= 56.66$$

7. CONCLUSION

Quantity and Quality of Distilled water obtained.

- Initially, water from the tap was filled into the outer pipe through the valve.
- 200 ml of distilled water was collected from the outlet in 1 Hr.
- The quality of distilled water from the outlet was tested in the form of the hardness of water.
- The hardness of tap water = 525 ppm
- The hardness of water obtained from outlet = 80 ppm
- The quality of the distilled water obtained was satisfactory.

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9. REFERENCES


BIOGRAPHY

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