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# Analysis of Energy Storage from Exhaust of an Internal Combustion Engine

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***ABSTRACT***
*The current highlighted problems are related to scarcity of energy, and the exhaust waste heat by the internal combustion engines which cause environmental pollution. The total heat supplied to the engine in the form of fuel is partially converted into useful mechanical work; rest will be ejected to the environment as exhaust gases which cause serious environmental pollution. Exhaust gas formed due to the combustion of fuels such as natural gas, gasoline/petrol, diesel, fuel oil or coal, which then discharged into the atmosphere through an exhaust pipe. The exhaust gas from an internal combustion engine carries away the heat of combustion in abundant form. The energy available in the exit stream of many energy conversion devices goes as waste, if not used properly. The main objective of the proposed project is to utilize heat from the exhaust gases of a diesel engine and convert heat to useful work. In the present work, a shell and finned tube heat exchanger integrated with an Internal Combustion engine setup to extract heat from the exhaust gas and a thermal energy storage tank used to store the excess energy available is investigated in detail. Energy supplied to an engine is the heat value of the fuel consumed. But only a part of this energy is transferred into useful work. From heat balance sheet of a typical IC engine, I found that the total heat loss is around 35–45%, of which 33% is due to exhaust gases and the rest is lost to the surroundings.*

**Keywords:** combustion, energy, exhaust gas, heat, scarcity

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## INTRODUCTION

The internal combustion engines are the major consumer of fossil fuel around the globe. Out of the total heat supplied, only 30 to 40% is converted into useful mechanical work. The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases dumped to environment.

The legislation of exhaust emission levels has concentrated on carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM). Energy conservation on engine is one of best ways to deal with these problems since it can improve the energy utilization efficiency of engine and reduces emissions [2].

## HEAT FROM I.C. ENGINE

Waste heat is generated in a process of fuel combustion or chemical reaction. Approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high up to 450–600°C.

**Benefits of 'Waste Heat Recovery'**

- Recovery of waste heat has a straight effect by decrease in the utility consumption and process cost.
- Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) etc., releasing to atmosphere. Recovering of heat reduces the environmental pollution levels.
- Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes.

## EXPERIMENT ON TWIN CYLINDER DIESEL ENGINE

Twin cylinder diesel engine specifications

- Vertical, double cylinder, water cooled, compression ignition, 4 stroke.
- Power output 10 h.p. running at 1500 rpm.
- Engine's moving parts are lubricated by force feed and partly by splash lubrication.
- Sensible centrifugal type governor mounted on the camshaft gear.
- Water cooled engine is cooled by air flow generated with the help of a fan mounted on the flywheel called conventional cooling.
- Test rig coupled with eddy current dynamometer loading.

To estimate the exhaust gas temperature, we conducted an experiment on the twin cylinder Diesel engine available so that the exhaust gas temperature could be estimated.
The engine was tested at different loads starting from 10 kg to 35 kg at different time intervals, by connecting a thermocouple at the engine's exhaust. The engine was running at a constant rpm of 1500 rpm.
The twin cylinder diesel engine was water cooled and a dynamometer was attached at the output.

| Sl. no. | Load (kg) | Temperature (Celsius) |
|---|---|---|
| 1. | 0 | 285 |
| 2. | 10 | 313 |
| 3. | 15 | 345 |
| 4. | 20 | 375 |
| 5. | 25 | 410 |
| 6. | 30 | 440 |
| 7. | 35 | 450 |

## EXPERIMENTAL REQUIRMENTS

I used the heat exchanger at the exhaust of twin cylinder diesel engine and a low boiling fluid i.e. Diethyl ether which used the heat from the exhaust pipe of the engine and vaporize the low boiling fluid which is further used to rotate the turbine which is basically other working unit attached to the engine. The heat used by the heat exchanger is used to vaporize the working fluid and there is reduction in the loss of exhaust heat as some heat is utilize by the external unit which is attached to the exhaust of the engine. The performance parameters pertaining to the heat exchanger and the storage tank such as amount of heat recovered, heat lost, and increased efficiency is evaluated.

**Selection of Low Boiling Point Fluid**

For the purpose of experiment a low boiling point fluid was selected from the list of low boiling point fluids. Taking into consideration all the aspects the most appropriate fluid was Diethyl Ether.

| Properties | |
|---|---|
| Molecular formula | $C_4H_{10}O$<br>$C_2H_5OC_2H_5$ |
| Molar mass | 74.12 g/mol |
| Appearance | clear, colorless liquid |
| Density | 0.7134 g/cm³, liquid |
| Melting point | −116.3°C (156.85 K) |
| Boiling point | 34.6°C (307.75 K) |
| Solubility in water | 6.9 g/100 ml (20°C) |
| Viscosity | 0.224 cP at 25°C |

## Properties of Diethyl Ether

Diethyl ether, also known as ether and ethoxy ethane, is a clear, colorless, and highly flammable liquid with a low boiling point and a characteristic odor.

## RESULT

The twin cylinder diesel engine was operated with diethyl ether which will extract the heat from the exhaust gas and hence convert it into steam by initially taking diesel oil as the working fluid and then introducing a low boiling point fluid. The mass flow rate of the low boiling point fluid was determined for optimum heat recovery. Due to the heat exchange, the liquid will become vapor and then it will be directed to the transducer. After conducting the experiment we found that the exhaust gas temperature increases with increasing load and reaches a maximum of $450^0$C for full load condition.

The results are recorded in the table:

| **Load (kg)** | **V (Volts)** | **I (A)** | **Time for 20 c.c. of fuel** | **Air inlet temp. (°C)** | **Exhaust gas temp. (°C)** | **Water inlet temp. (°C)** | **Water outlet temp (°C)** | **Vapor inlet pressure (bar)** | **Vapor outlet pressure (bar)** | **TFC (g/s)** | **Heat lost exhaust gas (kJ/hr)** | **Heat lost cooling water (kJ/hr)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 240 | - | 84 | 26 | 44 | 28 | 44 | 0.35 | 0.60 | - | 12912.6 | 19223.3 |
| 10 | 240 | 5 | 76 | 26 | 44 | 28 | 44 | 0.45 | 0.65 | 0.13 | 16435.5 | 19223.3 |
| 15 | 240 | 8 | 62 | 26 | 44 | 28 | 44 | 0.50 | 0.70 | 0.17 | 17910.4 | 19223.3 |
| 20 | 240 | 12.5 | 53 | 26 | 44 | 28 | 44 | 0.65 | 0.75 | 0.19 | 19607.4 | 19223.3 |
| 25 | 240 | 17.5 | 47 | 26 | 44 | 28 | 44 | 0.75 | 0.90 | 0.26 | 20905.3 | 19223.3 |
| 30 | 240 | 22 | 34 | 26 | 44 | 28 | 44 | 0.95 | 1.00 | 0.34 | 20981.5 | 19223.3 |
| 35 | 240 | 26 | 26 | 26 | 44 | 28 | 44 | 1.00 | 1.15 | 0.39 | 21853.4 | 19223.3 |

The experiment was carried out at different loads starting from 10 kg to 35 kg. The readings were also noted down for zero load case. When we used diethyl ether as the working fluid to extract heat we find that the exhaust gas temperature drops which may due to the heat extracted by the exhaust gas inside the heat exchanger

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