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Performance Analysis of IC Engine with Waste Heat Recovery by Heat Pipe and Biodiesel Blends: A Review

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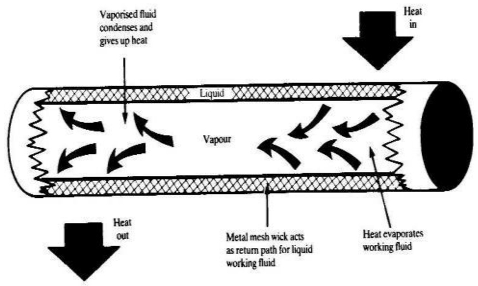
Abstract: ***Power is the ultimate need of hour throught the world. In the context of rapid economy development fueled by the energy, the exhaust waste heat from the IC Engine and its effect on environmental pollution has been recently more heavily emphasized. Also the threat of depletion of conventional fuels in the years to come by, has prompted to use renewable sources of energy such as Biodiesel. Around one third of useful heat energy is utilized as mechanical work while the similar amount is exhausted to atmosphere. The utilization of this waste heat by recovering with the use of heat pipe, not only increases the performance and efficiency of engine but also reduces the serious environmental pollution.***

Keywords: Efficiency, Emission, Waste heat, Biodiesel

1. Introduction

Internal combustion engine is used as 'prime mover' for the propulsion of automobiles. The efficiency of a typical internal combustion engine varies between 30% to 40% indicating that considerable amount of energy is wasted. It is a fact that only 30% to 40% of generated energy in an engine by the fuel gets converted into useful mechanical work and remaining almost 70% of the energy released due to combustion of fuel is lost mainly in the form of heat. If exhaust gases of internal combustion engines are released directly into atmosphere it will not only waste but also causes the environmental problems, so it can be utilized for useful work to increase the efficiency of engines. Among the various waste heat recovery devices, heat pipe has the greater advantages as it transfer up to 100 times more thermal energy than other best known conductor. The heat pipe consists of three elements –(i) a sealed container (ii) a capillary wick structure and (iii) a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum. Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapour because the container tube is sealed under vacuum. Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapour thus formed absorbs the latent heat of vapourisation and this part of the heat pipe becomes an evaporator region. The vapour then travels to the other end of the pipe where the thermal energy is removed causing the vapour to condense into liquid again, thereby giving up the latent heat of the condensation. This part of the heat pipe works as the condenser region. The condensed liquid then flows back to the evaporated region. Heat pipe is shown in Figure 1.



Also the availability of petroleum resources in near future is going to be a serious concern. Another, important concern is environmental degradation or climate change such as global warming. Global warming is related with the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. In the present thesis work, biodiesel is blended with diesel.

2. Related Works

Research and investigation have been done in accordance to recover and utilize the waste heat. Jumade (2) analysed on waste heat recovery from internal combustion engine by using Thermoelectric technology and found that major part of the heat supplied in an internal combustion engine is not realized as work output, but dumped into the atmosphere as waste heat. If this waste heat energy is trapped and converted into usable energy, the overall efficiency of an engine can be improved. The percentage of energy rejected to the environment through exhaust gas which can be recovered is approximately 30-40% of the energy supplied by the fuel depending on engine load.

Saidur (3) analysed on technologies to recover exhaust heat from internal combustion engine and found that there are large potentials of energy savings through the use of waste heat recovery technologies. The study also identified the potentials of the technologies when incorporated with other devices to maximize potential energy efficiency of the vehicles. Recovering engine waste heat can be achieved via various methods. The heat can either be ''reused'' within the same process or transferred to another thermal, electrical, or mechanical process. By maximizing the energy of exhaust gases, engine efficiency and net power can be improved. By increasing the energy efficiency, sustainability index will increase and leads to less production of pollutants like NOx and SO_2 during creating the same amount of power.

Frank Mucciardi (4) analysed on method of heat extraction using a heat pipe and observed that method of heat extraction from a material, comprising the steps of: providing a heat pipe assembly having an evaporator and a heat extracting condenser in fluid flow communication therewith, the evaporator comprising a flow modifier therein adapted to cause swirling of a working substance flowing in the evaporator, and the condenser being cooled to condense the vaporized working substance received from the evaporator; providing a discrete, impermeable liquid return passage between the condenser and a leading end of the evaporator; selectively permitting the flow, by gravity, of the liquid. Working substance from the condenser to the evaporator through the liquid return passage and placing the evaporator in heat transfer communication with the material to be cooled. Working substance can be selected according to the expected operating temperature range to which the working substance should be exposed during operation of the heat pipe assembly. If expected operating temperature range is greater than about 600° C, then the working substance must includes an alkali metal, whereas if expected operating temperature range is less than about 600° C then the working substance must be any one of Water, Thermex and Methanol.

Patil (5) analysed on single cylinder four stroke compression ignition engine exhaust system and observed that energy efficient exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions as well for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine.

Nadaf (6) analysed on waste heat recovery utilization from diesel engine and suggested that the recovery and utilization of waste heat not only conserves fuel (fossil fuel) but also reduces the amount of waste heat and greenhouse gases damped to environment. It also indicates the availability and possibility of waste heat from internal combustion engine. He found that only about 38% energy supplied to engine is converted into useful work,30% lost by means of exhaust gas,18% by cooling system ,7% by friction and radiation and another 7% by air after cooling.

The following technologies have addressed and having their own benefits by utilizing these new engine waste heat recovery technologies from the perspective of technical, economic, and environmental aspect:

- Recovering engine waste heat can be achieved via numerous methods. The heat can either be reused 'within the same process or transferred to another thermal, electrical, or mechanical process.
- Waste heat recovery entails capturing and reusing the waste heat from internal combustion engine and using it for heating or generating mechanical or electrical work.
- The common technologies used for waste heat recovery from engine include thermoelectric devices, organic Rankine cycle, air-conditioning and refrigeration and preheating of biodiesels using heat exchangers.
- The study identified that the incorporated technologies add maximized energy efficiency of the vehicles with improved power and reduced emissions.
- The waste heat recovery leads to less production of pollutants like NOx and SO_2 during creating the same amount of power.
- The idea of extract required heat for preheating biodiesels from exhaust gases in design such a device which can eliminate the use of this external power and can also reduce the temperature of the exhaust gases to a greater extent.
- It would also help to recognize the improvement in performance and emissions of the engine if these technologies were adopted by the automotive manufacturers.

Barnwal (7) analysed Biodiesel as an organic, non-toxic and biodegradable fuel made from everyday renewable resources, like vegetable oils or animal fats. It can power your car's engine and help the environment at the same time. It doesn't contain any petroleum, so forget about escalating gas prices. Biodiesel cuts down on CO2 emissions; in fact, it's the only alternative fuel to have fully completed the health effects testing requirements of the US Clean Air Act. Biodiesel can be purchased.

Mane (8) analysed that Indian Railways is successfully manufacturing biodiesel for the past 8 years at biodiesel production unit located at Loco Workshops Perambur in Chennai. Similar plants are being established at Raipur in Chhattisgarh and Tondiarpet near Chennai. Biodiesel is being used in blends of B5 and B10 for diesel engines of transport vehicles and locomotives. These locomotives have 2600 hp diesel engines and are mostly underutilized. As already Biodiesel is successfully introduced it can also be tried out in both of these workshops in days to come.

After reviewing the above mentioned literature it is therefore proposed to perform a research about the effect of intake heated air to the C.I. Engine by recovering the waste heat.

3. Proposed Work

The experimental analysis is being proposed to be conducted on the 4-stroke single cylinder compression ignition engine along with the fabrication of heat pipe which is supposed to be installed on the exhaust section of the engine. By recovering the waste heat from the exhaust gases, it is used to heat the intake air to be supplied to the engine cylinder which as a consequence reduces the fuel consumption and in turn increases the thermal and mechanical efficiency of internal combustion engine. The performance analysis of compression ignition engine is to be conducted by using biodiesel blends of B5 (Used cooking oil) as biodiesel fuel.

The specification of CI Engine and properties of fuel to be used has been shown in Table 1 and Table 2 respectively.

Table 1: Specification of Engine

S. No.	Parameter	Specification
1	Make	Kirloskar
2	Engine type (model)	Four Stroke, four valve
3	Fuel Used	Biodiesel Blended Fuel
4	Number of Cylinder	One
5	Rated Power Output (kW)	3.7
6	Bore [mm]	87.8
7	Stroke [mm]	110
8	Compression ratio	18.5:1

Table 2: Properties of Fuel

S. No.	Properties	Diesel	Biodiesel
1	Density(kg/m^3)	850	876
2	Calorific value (kJ/kg)	46,500	39,976
3	Kinematic viscosity @ 40 ºC	3.05	5.0
4	Cetane number	55	52
5	Flash point ºC	52	140
6	Fire point ºC	56	56
7	Specific gravity	0.84	0.87
8	Sulphur content (%)	<0.035	<0.035

4. Expected Result

On the basis of experiment which is proposed to be conducted on a single cylinder four stroke compression ignition engine by making modifications in the exhaust of the engine while using Biodiesel blended fuel, the expected result made:

- The Brake thermal efficiency of the engine is likely to increase with the increase in percentage of warm air.
- The Indicated thermal efficiency of the engine is likely to increase with the increase in percentage of warm air.
- The Brake specific fuel consumption of the engine is very much expected to decrease with the increase in percentage of warm air.

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