Analytical and Experimental Investigation on Engine Waste Heat Recovery for Utilization in Food Delivery Vehicle

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Abstract— Recent trend regarding the most effective ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fuel as well as pollution. Out of all the earth's sources, the internal combustion engines are the main consumer of the fuel round the globe. Out of the whole heat provided to the engine in the form of fuel, about thirty to forty percent is converted into useful mechanical work; remaining heat is expelled to the surroundings through exhaust gases, engine cooling systems and radiation, that causes entropy rise and high environmental pollution, therefore it's needed to utilize waste heat into useful work. For this a system comprises with a combination of heat exchangers is used to extract the waste heat of automobile and utilize this heat to keep food warm in food delivery vehicle as maintaining temperature and quality of food in food delivery is the major problem. A coil type heat exchanger integrated with an IC engine and heat exchanger mounted on fins are used to extract heat and this heat is used to keep the food items warm in the delivery box by placing another heat exchanger in a food delivery box which rejects heat into the box.

Key words: Exhaust heat; Waste Heat recovery; Food delivery vehicle; food delivery box; Heat Exchangers

I. INTRODUCTION

Internal combustion engine runs on fossil fuels. Out of the total heat provided to the engine in the form of fuel, about 35% is converted into useful mechanical work; remaining heat is lost to the surroundings through exhaust gases, engine cooling systems and radiation as shown in the below figure, so utilization of the waste heat from the internal combustion engine is required.

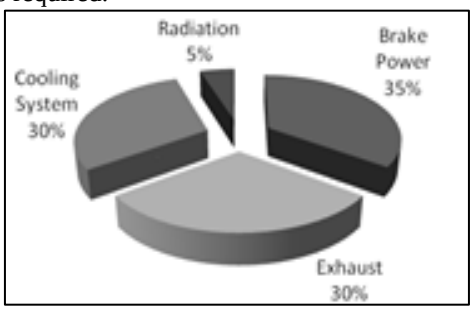

Fig. 1: Heat losses from I. C. Engine

In specific, interest in food delivery vehicle is due to increasing on-line food delivery items like pizza, Burger etc. However to deliver the ordered food item needs time of about 20-30 minutes. Meanwhile the food items get cooled and lose its taste. Therefore either client has to heat it or to eat as it is. To avoid this loss of food quality, some arrangement ought to be created which is able to solve this drawback. If the delivered food is warm then client gets additional satisfaction and this can attract additional customers to order on-line food which will ultimately increases the business. To recover this waste energy, one of the ways is by using heat exchanger. Heat exchangers are used to extract heat from the exhaust which anyway is going as a waste and use this heat to heat food in a food delivery vehicle.

II. LITERATURE REVIEW

Pradip G. [1] used four stroke, Single Cylinder, water cooled Diesel Engine and they connected Heat wheel to the engine exhaust piping. The Air intake heater system for an engine consists of the following: 1. Heat wheel to be positioned with an intake and exhaust gas passage way of an engine. 2. A speed controller to regulate power to the heat wheel by switching on and cutting of as when necessary. 3. Temperature sensor to give temperature at inlet and outlet air flow in heat wheel. The fresh air is taken from atmosphere through air filter and then it is passed through the heat wheel. On the other hand the hot exhaust gases from engine are passed through the heat wheel in counter flow direction. During the rotation of heat wheel the heat exchange from engine exhaust to fresh air takes place and air gets heated. This hot air is then provided to engine cylinder through filter. And exhaust gases are exhausted in atmosphere. The test is conducted at different engine loads and different heat wheel speeds. Temperature of intake air is dependent on the speed and wire mesh density of heat Wheel. Heat Input required for the engine decreases with increase in intake air temperature. Since heat input decreases with increase in intake air temperature Brake Thermal Efficiency also increases. It also reduces the environmental pollution. The CO content in exhaust gas slightly decrease and NOx content slightly increases with increase in intake air temperature, the CO2 and O2 content remains unaltered.

Mr. Krishna Asawa [2] converts standard delivery box of pizza delivery vehicle by adding copper sheet and baffles at bottom side. There are two chambers, one is heating chamber and another is food chamber. The chamber is separated by a copper plate. Copper plate is mounted to the delivery box wall with facilitate of stuff and it's made air tight in order that there mustn't be any leak of exhaust gas from bottom chamber. The bottom chamber consists of baffles that are provided to guide the flow of exhaust gas in zigzag fashion.. The inlet and outlet port is provided on the bottom side. Pipe connector is mounted at inlet in order that pipe ought to fix on that properly. Outlet port has bend pipe connector in order that the exhaust gas ought to be discharged into the atmosphere. The exhaust gas from the muffler is carried to the heating chamber with help of connecting pipe. The pipe is connected to the inlet connector. The exhaust has entered into the heating chamber then is allowed to pass in zigzag manner with the help of baffles. While moving through the baffles the warmth from the exhaust gas is conducted to the copper plate then it's convected to the food chamber. The discovered performance is well once the vehicle is running continuously. However once the vehicle

stops and again started after a while, it takes about quarter-hour to achieve the required temperature. There's variation of temperature on copper sheet from inlet to outlet; this affects the heat transfer coefficient. So the plate thickness has more importance because it is needed to possess optimisation of strength of plate and heat transfer coefficient. The pressure drop because of set up results in drop in engine efficiency that is considerable. Adding the set up will increase the fuel consumption however this provides the client quality food which can increase the client satisfaction.

III. PROBLEM IDENTIFICATION AND OBJECTIVE

From the literature survey, it is found that the waste heat from IC Engine is not recovered properly. There are problems like pressure drop, increase fuel consumption, decrease in efficiency etc. Also Online food business is increasing day by day. There are problems regarding food delivery like bad quality, poor packing, different taste, timing, etc. When delivering meals it's important for every business to make sure it reaches fresh, hot. But maintaining temperature in food delivery is the major problem.

Objective of this research is to recover the waste heat from IC Engine without affecting the performance and efficiency of the engine and make the device that maintain temperature and quality of food as well as same in dimensions and cost to existing system and use it in food delivery vehicle. This food delivery system can capable to fulfill requirement of quality and temperature in long distance. This new mechanism will indirectly boost any economy that depends on food delivery.

IV. EXHAUST GAS TEMPERATURE VARIATION WITH RESPECT TO TIME

The engine used in this experiment is Single Cylinder 2-valve, DTS-i with ExhausTEC (DISCOVER 125). The temperature at the starting of the bike silencer is measured with temperature gun and the variation in temperature with respect to time is shown by the following graph.

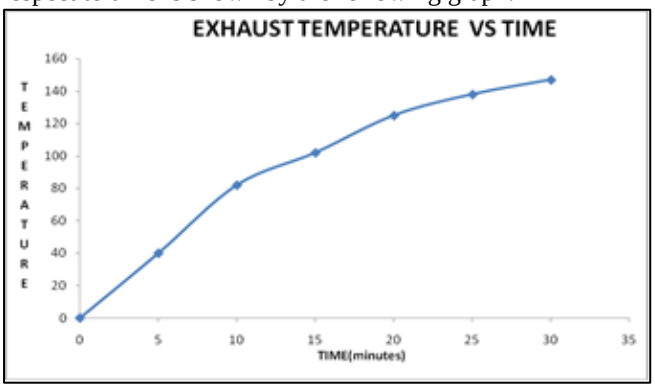

Fig. 2: Temperature of exhaust gas Vs Time

So it is clear from the graph that after 15 minutes we get above 100oC temperature and it keeps on increasing further. The following temperatures are measured when the ambient temperature is 25.c.

V. AVAILABILITY OF WASTE HEAT FROM THE EXHAUST OF I.C ENGINE

The quantity of waste heat is a function of both the temperature and the mass flow rate which contained in exhaust gas.

Heat loss in exhaust gas (QE) = ṁE × Cp × ΔT
Where:
QE = Heat loss in kJ/min
ṁE = Exhaust gas mass flow rate in kg/min
Cp = Specific heat of exhaust gas in kJ/kg °K, and
ΔT = Temperature gradient in °K.
In Table the engine specification is given. Heat loss through the exhaust gas from internal combustion is calculated as follows:
Assuming,
Volumetric efficiency (ηv) = 0.8 to 0.9
Petrol fuel density = 0.71 to 0.77 gm/cc
Calorific value of diesel = 43 to 45 MJ/kg
Air fuel density = 1.207 kg/m3
Specific heat of exhaust gas = 1.1-1.25 kJ/kg °K

Manufacturer	Bajaj Auto Limited
Engine	Single Cylinder 2-valve, DTS-i with ExhausTEC
Displacement	124.6 cc
Bore	57 mm
Stroke	48.8 mm
Compression ratio	10.8:1
Sp. Fuel consumption	0.25kg/bhp.hr
Max. power	10.9 BHP @8000 rpm
Max. Torque	10.8 N.m @5500 rpm
BHP@1500 rpm	2.04 BHP
Cooling system	Air cooled

Table 1: specification of engine (discover 125)

Exhaust heat loss through petrol engine:
Compression ratio (r):
r = (Vc+Vs) / Vc
Where Vc= Clearance Volume Vs= Swept Volume
10.8= (Vc+124.6×10-6 m3) / Vc
Vc = 1.27 × 10 -5 m3
Total volume (Vt) = Vc + Vs
=124.6×10-6 m3 + 1.27 × 10 -5 m3
=13.67 × 10 -5 m3

Mass flow rate of fuel (on the basis of specific fuel consumption) ṁf
s.f.c = ṁf / power
ṁf = 0.25Kg/bhp.hr × 2.04 bhp
=0.51 Kg/hr
=1.416 × 10 -4 Kg/sec
Volume rate = swept volume × speed
Volume rate (V) = Vs × N
= 124.6×10-6 × 1500/2 m3/ min
=0.09345 m3/ min
=1.557×10-3 m3/ sec
Volumetric efficiency (ηv)
ηv = volume of air/ swept volume
ηv = ṁa / ρa × n × Vs
ṁa = ηv × ρa × n × Vs
= 0.9×1.2×1500/2×124.6×10-6
=0.1009Kg/min
=1.6821×10-3 Kg/sec
Mass flow rate of exhaust gas (ṁE)
ṁE = ṁf + ṁa
= 1.416 × 10 -4 + 1.6821×10-3 kg/ sec
=1.8237×10-3 kg/ sec
Heat loss in exhaust gas (QE) = ṁE × Cp × ΔT
= 1.8237×10-3×1.1× (150-25) kJ/sec (or kW)

=0.25 kJ/sec (or kW)
=250 watts

This heat loss in exhaust gas is the loss when the vehicle is running at 1500rpm. Normally we drive the vehicle at 4000 rpm so the heat lost at 4000 rpm is 0.83KJ/sec. That is 49.8KJ/min. So if the vehicle runs for 15minutes, heat loss will be 747KJ.

VI. EXPERIMENTAL SETUP

Following components will be used in Experimental Setup:-

- Coil type heat exchanger
- Heat exchanger mounted on fins
- Flexible hose pipes
- Heat exchanger in box
- Fan
- Flow control valve
- Temperature sensor (LM 35)
- Microprocessor (Arduino atmega328)
- Battery (12 V)
- Couplings

A. Coil type heat exchanger:

This heat exchanger is connected on the exhaust outlet of the engine. Main reason to use coil type heat exchanger is to increase the connecting area of the Heat exchanger and because of the shape of exhaust silencer pipe. Temperature of exhaust in motorcycle is approximately 100-150 .C after 15 minutes of the vehicle running. The no. of turns is 12 and the diameter of coil is 8mm. The coil is hollow so that the heat transfer fluid flows inside the coil. This fluid is used to extract heat from the exhaust and transfers this heat into the box.

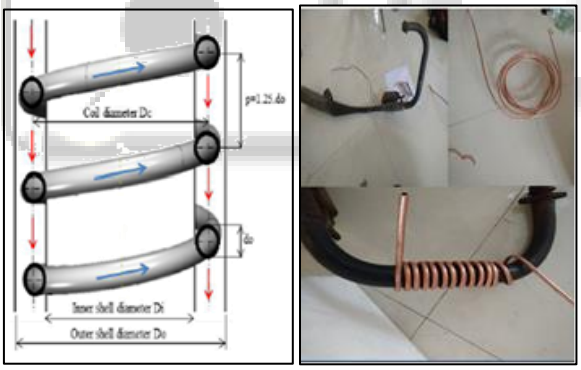

Fig. 3: Coil type heat exchanger

B. Heat exchanger in box:

It is the second heat exchanger used in this design and it is mounted in delivery box. This is used for heating said space in delivery box. High temperature fluid from the coil type heat exchanger comes to the delivery box and supply heat to the food which is kept in said space. So fluid rejects heat and maintains the temperature of food.

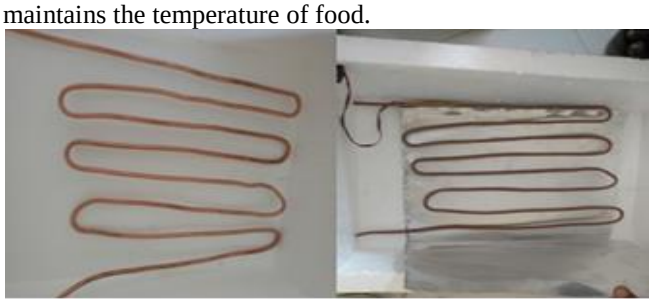

Fig. 4: Heat exchanger in Delivery box

VII. METHODOLOGY OF WORKING

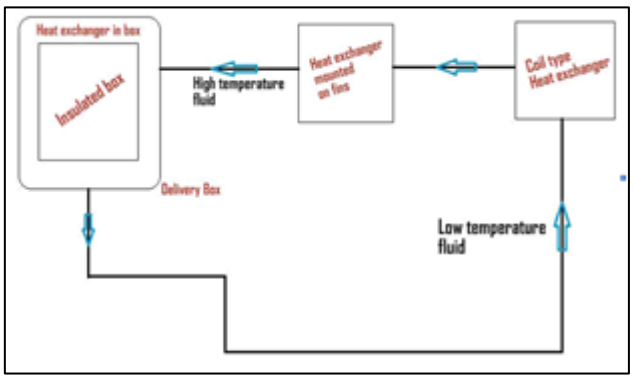

Fig. 5:

Low temperature fluid which is used in heat exchanger process goes to the coil type heat exchanger which is mounted on exhaust pipe of engine then it goes to the second heat exchanger which is mounted on fins of the engine. Temperature of exhaust pipe is less than the temperature of engine so first fluid goes to coil type heat exchanger and then in heat exchanger mounted on fins.

Now we have high temperature fluid which we will use to maintain the temperature of delivery box. This high temperature fluid goes to heat exchanger in the delivery box where it gives heat to food and maintains the temperature of food. This process repeats again and again.

VIII. CONCLUSION

From this research, It is concluded that with the help of this arrangement it is possible to recover 15-20% of the heat & maintain the temperature up to 55oc within 15-20 minutes in the food delivery box by utilizing waste heat of exhaust gas from IC Engine. Hence this system is capable to fulfill requirement of quality and temperature in long distance also.

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REFERENCES

[1] Pradip G. Karale , Dr. J. A. Hole ,Waste Heat Recovery from Engine Exhaust by using Heat Wheel, e-ISSN: 2278-1684,p-ISSN: 2320-334X, PP 84-87,2015

[2] Mr. Krishna Asawa, Prof. Vaibhav Dighe, Use of exhaust gas heat to keep food delivery item warm, Vol-2 Issue-3 2016 IJARIIE-ISSN(O)-2395-4396
[3] Er. R. K. Rajput., "Heat and mass transfer, Fifth edition," (S. Chand Technical, 2012), 1-24, ISBN: 81-219-2617-3

