Review Article

EXPERIMENT ON ENHANCING HEAT TRANSFER - EGT USING TURBULENCE PROMOTERS AND CROSS FLOW HX WITH DI/AG+ NANO PARTICLES

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ABSTRACT

Thermal Engines (TE), either Diesel Engines (DE) or Internal Combustion Engines (IEC) are the most important industrial prime movers used in automobile, manufacturing, aerospace sectors etc. TE's operate by chemical combustion of fuels and 60 – 70% unused thermal energy carried out by the exhaust gases. In this paper, methodology for recovering waste heat energy of exhaust gas of diesel engine is presented by placing a heat exchanger in the exhaust manifold so that energy from the exhaust gases can be used for preheating the fuel.

Effectiveness of heat exchanger depends on the convection heat transfer coefficient of the fluid. Maximum fuel temperature achieved for counter flow arrangements at 50% of full load at 1440 rpm. Waste heat recovered at 50% full load condition is found to be 72%. Internal Spleen Pipes structured Turbulence promoters are used in enhancing the heat transfer and mass flow rates in the given section. Variable liquid flow rate in the range of 50 lph to 200 lph is used and air velocity in the range of 14.0 m/s to 20.0 m/s. The fluid inlet temperature was varying from 40°C to 135°C to find the optimum inlet condition.

Ultrahigh performance cooling is one of the important needs of many industries. However, low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required for cooling purposes. Nanofluids are engineered by suspending nano particles with average sizes below 100 nm in heat transfer fluids such as water, oil, diesel, ethylene glycol, etc. Convective heat transfer coefficient of water, Alum - Water, Ag+ NP-water of 2% nanoparticle concentration has been calculated for counter flow heat exchanger. These suspended nanoparticles can change the transport and thermal properties of the base fluid. It is found that convective heat transfer coefficient of Ag+ - DI water, Alum- DI water nanofluids are 81 % and 66% higher compared to pure water respectively. It is found that overall heat transfer coefficient of Ag+ NP – Di water, Alum-DI water nanofluids are 23%, and 20% higher compared to pure water respectively. Results demonstrate that increasing coolant flow rate an improve the heat transfer performance. Also increasing the air flow rate improves the heat transfer rate. The rate of heat transfer enhancement was found 19% to 42% in comparison with pure water.

INTRODUCTION

Thermal engine/ (s) have played an important part and consumed more than 60% of fossil fuel, thus it was able to result in exhausting the fossil fuel. IEC's are the major consumer of fossil fuels, however only about 30-40% energy of combustion in the engine chamber was transformed into useful mechanical work [1-4]. The rest heat source expelled to the environment or lost through exhaust gases and cooling water/oil were approximately 60 - 70%, hence it was necessary to utilize and recover the waste heat to increase the heat efficiency of IEC. The waste heat recovery (WHR) and utilization not only saved energy but also reduced the toxic pollution. Engine manufacturers have implemented and improved the latest techniques to increase thermal efficiency by enhancing the fuel-air mixing, using turbo-charger, and variable valve timing or lean combustions engine development etc. [5-7].

During engine running, four sources of Waste Heat (WH) such as exhaust gas, cooling oil/water/liquid, lube oil, and turbocharger were dissipated to the atmosphere from the engine. Waste Heat (WH) depended on not only the temperature of the waste heat gases, but also mass flow rate of exhaust gas of engines. Exhaust gas temperature of DE after leaving the engine were as high as 450 - 600°C. Consequently, the higher the exhaust gas temperature was, the higher the heat value. But, the temperature of exhaust gases are constrained by

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the laws of thermodynamics. Total energy from diesel engines was shown in the Figure 1.
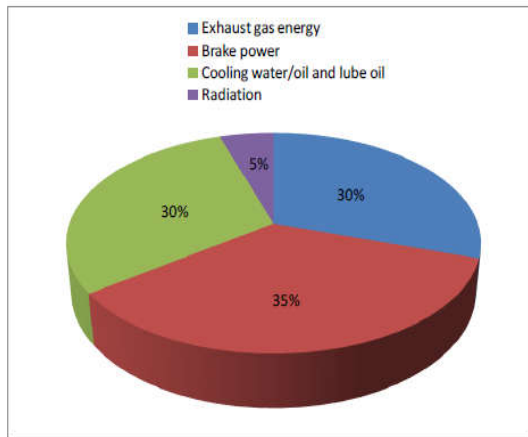

Figure 1. Total energy in diesel engines

Table 1: Various Engine and There Output (K.T.Wojciechowski)

Engine Type	Power Output (kW)	Waste Heat
Small air cooled diesel engine	35	
Water air cooled engine	35-150	30-40 % of energy waste loss from IC engines
Earth moving machineries	520-720	
Marine applications	150-220	
Trucks and road engines	220	

WH recovery from diesel engines brought many big benefits not only high power engines, but also smaller engine. Benefits from WH recovery might be divided into direct or indirect benefits.

Direct benefits: Recovery of WH from DE increases the efficiency of combustion process; owing to pre-heating the fuel and increased atomization enhancing lean combustion and higher thermal efficiency. Hence WH recovery was considered a solution with lower costs, cutting emissions, and especially, increasing the EEDI (Energy Efficiency Design Index).

Indirect benefits: Some indirect benefits from WH recovery are pollution reduction, the device size reduction etc. Increased combustion directly relates to reduced particulate suspension in the exhaust system. Conventional wisdom signifies that, size of particulate suspension in the exhaust is inversely proportional to fuel consumption. Reduction in energy consumption for auxiliary devices such as boiler, compressors etc. Many researchers about recovering the WH both on diesel engines [1] and gasoline engines [2] have been carried out. The results of combination of ETC (Electric turbo compound) and TEG (Thermo-electric generator) led 3% to 5% of fuel saving and 1% to 4% of CO2 reduction [3] as this combination system was installed in was noticed. A combination between a TEG and an

Organic Rankine cycle (ORC) system aiming at recovering the WR energy was investigated by [4 -5] showed the way of recovering the WH from exhaust gases of ICE by using Organic Rankine Cycle (ORC) system. In this case, the engine power increased in comparison with 3.4% of the flow rate of fuel energy on average. However, the average flow rate of fuel energy increased up to 5.1% with 8.2% of top improvements if combined two ORCs. It was also found that, pure vegetable oil was the fuel rapidly growing in use, and it should have good fluidity, low viscosity and good atomization which can only possible by preheating. There were many researchers used heating method to heat up pure vegetable oil aiming at direct using in diesel engines[8] used Kusum oil for small diesel engine and shown that viscosity was close to diesel's by preheating to$100\,^{\circ}C.-130^{\circ}C$.

Problem Definition

The rapid economic development and relative shortage of electricity, the IEC exhaust waste heat and environmental pollution has been more emphasized heavily recently. From the total heat supplied to engine around 30 to 40% is converted into useful mechanical work; the remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, hence it is required to utilize waste heat into useful work. The recovery and utilization of waste heat not only conserves fuel (fossil fuel) but also reduces the amount of waste heat and greenhouse gases dumped into the environment. Latest research efforts relating to combustion engines and vehicle design are largely driven by the increasing need to reduce the global consumption of fossil energy and the resulting emissions of the greenhouse gas carbon dioxide.

In lieu of present consumption rate, the world's proven oil reserves will expire in approximately 52 years, while the prognosis for natural gas is 54 years [2]. The combustion of fossil fuels generates CO_2 emissions, which absorb re-radiated heat from the earth's surface and thereby contribute to global warming. This anthropogenic greenhouse effect alters natural marine and terrestrial carbon cycles, reducing the environment's capacity for CO_2 storage [4]. The largest share of the globe's CO_2 emissions (45%) originated from fossil fuels burned for energy generation. Overall CO_2 emissions have increased by 80% since 1970 (and those from the transportation sector have increased by more than 100%), contributing to an average atmospheric temperature increase of around 0.8 °C over the same period [5].

Hydrocarbon and Carbon Monoxide Control: Diesel oxidation catalysts (DOC) have been applied to engines for more than 20 years, unfortunately they are still in infancy stage. They serve two primary purposes to oxidize hydrocarbons (HC) and CO that is inherently in the exhaust or added to provide fuel for regenerating a DPF, and to generate NO_2, which is used to oxidize soot on a continuous basis or for improving the low temperature performance of SCR catalysts. The Pt/Pd ratio is much more important to NO_2 formation than precious metal loading on the DPF [29].

Heat Recovery Chances in Engine: 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. This heat depends in part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes e.g. consider internal combustion engine approximately 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems [4]. It means 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 as 450-600°C. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reverberatory engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases [5]. Fig. 1 show total energy distributions from internal combustion engine.

Heat Recovery System For Engine Heat Recovery: Large quantity of hot flue gases is generated from internal combustion engine etc. If partially waste heat is recovered, a considerable amount of primary fuel could be saved. It is depends upon mass flow rate of exhaust gas and temperature of exhaust gas. Though, engine energy lost in waste gases cannot be fully recovered. There are different methods of the exhaust gas heat recovery namely for space heating, refrigeration and power generation. The mass flow rate of exhaust gas is the function of the engine size and speed, hence larger the engine size and higher the speed the exhaust gas heat is larger. So heat recovery system will be beneficial to the large engines comparatively to smaller engines [47]. The heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption cycle. These cycles are proved for low temperature heat conversion in to the useful power. The diesel engine exhaust gas waste heat recovery rate increase with increasing diesel engine exhaust gas emission rate.

Turbulence Promoters

Heat transfer enhancement techniques improve the heat transfer coefficient which brings about a reduction in the heat transfer area or the increase of the heat transfer capacity. The main feature of turbulence promoters (TP) is that they reduce the laminar boundary layer next to the walls which is the major resistance to heat transfer inside a tube. This technology is considered a key heat transfer enhancement due to their high performance, low cost, ease of construction, simple installation and removal for cleaning. They can be made on almost any material of construction such as aluminum, copper, carbon steel and stainless steel, among others. The main types of turbulent promoters are the twisted tapes [1-5,] winglets tapes [6,7] circular rings [3,8], baffles [9], helical inserts [10] and coil-wires [11]. Research has been focused on these geometries seeking to optimize their design.

Thermo-hydraulic Traits

The main heat transfer features emerging from the application of turbulence promoters are described below:

✓ The reduction of the hydraulic diameter due to blockage that inserts induce an increment in the fluid velocity: this in turn, increases pressure drop resulting in increased heat transfer inside the tube.
✓ As the Eddy flow increases inside the system, higher turbulence is created near the tube Wall bringing about the rupture of the laminar boundary layer. Fins or protrusions on the inserts increase turbulence.
✓ Eddy Flow promotes the mixing between the fluid in the central region and the one near the wall. This brings about temperature uniformity inside the tube.
✓ Some promoters contain holes along its length seeking to reduce the impact on pressure drop.

Performance Comparison Methods

One of the most widely used performance parameters used to measure the improvement of heat transfer is the Thermal Enhancement Factor (η). The term assumes that the pumping power between the bare tube and the tube with inserts are the same.

$$(V) \cdot (\Delta P) \, p = [V \cdot \Delta P] \, s \qquad (1)$$

The relationship between the friction factor and the Reynolds number is given by:

$$\left(f \cdot Re^3 \right)_p = \left(f \cdot Re^3 \right)_s$$

Or

$$(Re_s) = Re_p \left(\frac{f_p}{f_s} \right)^{\frac{1}{3}}$$

$$\eta = \frac{h_p}{h_s}\bigg|_{pp} = \frac{\left(\frac{Nu_p}{Nu_s} \right)}{\left(\frac{f_p}{f_s} \right)^{\frac{1}{3}}}$$

The Thermal Improvement Factor (η) is defined as the ratio between the heat transfer coefficient, h_p, of the tube with the insert and that of the bare tube h_s.

Counter Flow Heat Exchanger

The engine tests were conducted on single cylinder four-stroke diesel engine test rig, water cooled with a compression ratio of 16.5:1, running at a speed of 1440rpm with 5 HP rated power output. It was directly coupled to a rope brake dynamometer that permitted engine motoring fully or partially. Following is the methodology adopted.

A simple shell and tube heat exchanger is used in the exhaust line as a preliminary design as shown in fig 2. Here the fuel pipe line is initially passed through the exhaust manifold and then connected to the fuel injector. T_4 and T_5 are exhaust gas temperatures before and after pre-heating. T_1 and T_6 are fuel temperatures at inlet and exit of heat exchanger. Engine is made to run at different loads and temperature of both fuel and exhaust gas is recorded. Here, exhaust gas flow rate is left uncontrolled. Injection timing is observed to be at TDC.
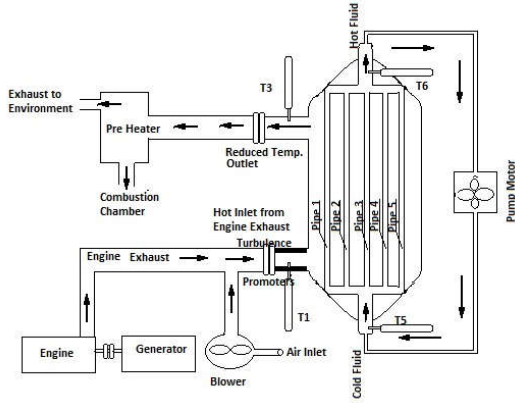
Figure 2

Waste Heat Recovery Waste heat recovery represents the amount of waste heat of the exhaust gas absorbed by the fuel in the heat exchanger. It is obtained as percentage of waste heat recovered which is given by the ratio heat absorbed by fuel to heat carried away by exhaust gases. This is calculated as follows. Heat carried away by exhaust gas is given by

$$Qe = M_e \, Cp_e \, (T_5 – T_4) \qquad (2)$$
Where,

Me   = Mass of exhaust gas in kg/sec.
Cpe = Specific heat of exhaust gas J/kg K.
T_2 = Exit temperature of gas °C.
T_1 = Inlet temperature of gas °C.

Heat absorbed by the fuel is given by

$$Q_f = M_f \, Cp_f (T_1 – T_6) \qquad (3)$$

Where,

M_f = Mass of fuel in kg/sec.
Cp_f = Specific heat of fuel in J/kg K.
 t_2 = Exit temperature of fuel °C.

T1 = Inlet temperature of fuel °C.

Then, percentage of heat recovered can be calculated as,

$$\%Qrec = (Qf/Qe) \times 100 \qquad (4)$$

Effectiveness: Effectiveness (ε) of a heat exchanger is an important parameter which signifies ability of heat exchanger to transfer heat from hot fluid to cold fluid. In order to compare the performance of counter flow heat exchanger used in this experiment, this term is used as significant factor.

NTU (Number of Transfer Units) can be calculated using the formula,

$$NTU = (UA/C_{min}) \qquad (5)$$
Where,
C_{min} = Minimum capacity rate in J/sec K
M_h, M_c = Mass flow rate of hot and cold fluid, Kg/s.
C_{ph}, C_{pc} = Specific heat of hot and cold fluid, J/Kg K
U = Overall heat transfer coefficient W/m^{2}K
A = Surface area of heat exchanger, m^2

'U' is calculated using hi and ho i.e. heat transfer coefficients at inlet and outlet of tube which depends on coorelation of Nusselt number, Reynolds number and Prandtl number relation

applied for internal flow through pipe and across the pipe considerations. Finally U is given by,
$$U = 1/((1/h_i) + (1/h_o)) \qquad (6)$$

Heat Exchanger Design

In this experiment, a shell and tube heat exchanger design is used. Shell is a tube connected to exhaust pipe of same diameter. So it is important here to design the tube length and number of turns for the tube. It is done as follows.

We know that,

heat transfer through heat exchanger is given by

$$Q = U \, A \, (LMTD) \qquad (7)$$
Where,
Q = Heat exchanged, W
U = Overall heat transfer coefficient W/m2K
A = Area (m2)
LMTD = Logarithmic Mean Temperature Difference

LMTD for counter flow is given below,

$$LMTD = \{[(T_4 - T_6) - (T_5 - T_1)]/ \ln ((T_4 - T_6)/ (T_5 - T_1))\} \qquad (8)$$

Then area A required for heat transfer can be calculated by
$$A = \pi \, d \, L. \qquad (9)$$

Where,
d = outer diameter of tube, m
L = Length of the tube.

To determine Number of Turns required, the formula used is,

$$N = \frac{L}{\sqrt{(2 \pi r)^2 + (3r)^2}} \qquad (9)$$

Where,

N = Number of turns
L= Length of the tube.
r = Radius of the shell.

Ag^+ NP as coolant fluid

One of the main difficulties in the accomplishment of the synthesis experiment of metal nanoparticles is the obtaining of stable colloidal suspensions, since metallic nanoparticles have a high surface energy, favoring thermodynamically the immediate aggregation of these for the formation of metal-metal bonds. [19]

To avoid the aggregation of nanoparticles, the preparation of colloidal systems is generally carried out in the presence of species called stabilizers, which adsorb on the surfaces of the nanoparticles, forming a self-organized layer that prevents coalescence. To this end, some of the most effective stabilizers are polymeric, for example, poly vinyl pyrrolidone (PVP), [20] poly (vinyl alcohol) (PVA) [21] and polyacrylic acid (PAA) etc.

The stability of these suspensions was guaranteed by the presence of borohydride and citrate ions that adsorb on the surfaces of the nanoparticles, generating electrostatic repulsions between them. Therefore, in order to achieve such a

condition, the excess addition of the sodium borohydride and sodium citrate reducing agents in the synthesis of the nanoparticles in question is required. [9,23]

Preparation of Silver Nanoparticles

Reagents

For the synthesis of the silver nanoparticles the silver nitrate reagents PA (Synth) and sodium borohydride 98 +% (Acros) powder were used. The gold nanoparticles were prepared from 99% tetrachlorouronic acid (Aldrich) and sodium citrate PA (Synth). The stability tests of the nanoparticles were performed with solutions prepared from sodium chloride (Vetec) with a minimum purity of 99%. Poly (vinylpyrrolidone) (PVP, Aldrich) and polyvinyl alcohol (PVA, Aldrich) were used on alternate days to stabilize the nanoparticles. 98% cystamine (Aldrich) was used in the stability tests of gold nanoparticles. All aqueous solutions were prepared with distilled water.

The alcoholic potash solution for cleaning the glassware was prepared with 1.0 L of 95% ethanol, 120 g of 85% potassium hydroxide (Synth) and 120 ml of distilled water.

PVA is not as water soluble at room temperature as PVP, therefore, in the preparation of the 0.3% PVA solution, the amount of 0.3 g of PVA was mixed with 100 ml of distilled water in an autoclave of stainless steel and the final set was kept in an oven at 120 ºC for a period of 25 min. [17]

Synthesis of silver Nanoparticles

Prior to the start of the experiments, all the glassware used was washed thoroughly with the alcoholic potash solution and distilled water. Any impurity present in the medium can serve as a nucleation site and promote the aggregation of the nanoparticles in solution. At this stage, it is extremely important that the teacher (s) is very demanding with the cleaning of the glassware.

In a 250 mL Erlenmeyer, 75 mL of a 2.0×10^{-3} mol L^{-1} solution of sodium borohydride was added. The flask was then placed in an ice bath for 10 to 15 min. Thereafter, a magnetic stir bar was placed in the flask and the assembly was brought to a stirring plate.

With the aid of a burette, 25 ml of a 1.0×10^{-3} mol L^{-1} solution of silver nitrate were added dropwise . This addition occurred within a period of approximately 4 min and with an addition rate of 1 drop s^{-1} . A standard yellow solution was obtained which immediately had its electronic spectrum obtained. The wavelength of maximum absorption was recorded and the value of the width at half height of the band surface plasmons was estimated. [9]

Heat Transfer using Internal Spleen Vertical Test Section

dia inner = 50 mm											spleen = 5mm x 5mm x 146 mm			
T_1	T_2	T_3	T_4	T_5	T_6	tavg.	h	k	Nu	V_{air}	γ	Re	Pr
54	53	47	49	58	49	51	382336	0.02735	279587.62	14	1.7980	15572.86	0.7202
52	52	49	49	54	47	50	382336	0.02735	279587.62	14	1.7980	15572.86	0.7202
46	49	48	46	53	45	48	690846	0.02699	511927.59	14	1.7500	16000.00	0.7228
46	48	47	45	52	44	47	690846	0.02699	511927.59	14	1.7500	16000.00	0.7228
45	47	48	45	51	44	47	923787	0.02699	684540.59	14	1.7500	16000.00	0.7228
45	47	47	45	50	43	46	814000	0.02699	603186.97	14	1.7500	16000.00	0.7228
45	46	48	45	50	43	46	1158078	0.02699	858153.09	14	1.7500	16000.00	0.7228
46	46	47	45	50	43	46	1393728	0.02699	1032773.79	17	1.7500	19428.57	0.7228
45	46	49	45	51	43	47	3577818	0.02699	2651217.14	17	1.7500	19428.57	0.7228

Heat Transfer using Nano Fluids in Heat Exchanger @ 6 lts/ min.:

Sl. No	Hx Inlet – Hot Air			Cold Fluid – DI/ Alum				Hx Inlet – Hot Air			Cold Fluid – DI/ Ag⁺ NP			
	T_{amb}	T_{ch}	T_3	T_4	T_5	T_6	$T_{avg.}$	T_{amb}	T_{ch}	T_3	T_4	T_5	T_6	$T_{avg.}$
					@ Inlet Velocity of 14 m/s									
1.	53.0	54	48	49	58.5	49.0	51.1	74	58	50	49	58.5	38.5	42.7
2.	52.5	52	49	49	54.7	47.0	50.0	73	54.2	51	49	54.7	38.2	42.9
3.	51.5	46	48	46	53.2	45.0	48.1	72.7	54.2	51	46	53.2	38.2	43
4.	50.5	46	48	45	52.2	44.2	47.5	71.2	54	52.5	45.7	52.2	37.7	43.2
5.	50.2	45	48	45	51.7	44.2	47.3	71	53	53	45.5	51.7	38.2	43.2
6.	49.2	45	48	45	50.7	43.5	46.8	69.5	51.2	53	45.2	50.7	37.7	43
7.	47.7	45	48	45	50.5	43.0	46.7	70.5	52	53	45	50.5	38	42.9
					@ Inlet Velocity of 17 m/s									
8.	47.0	46.0	47.2	45.0	50.7	43.5	46.6	70.5	58.7	55	45	50.7	37.5	43.7
9.	47.5	45.7	49.7	45.2	51.0	43.7	47.4	70.5	56	56	45.2	51	38.5	44.2
10.	46.7	45.7	50.5	45.2	51.2	44.0	47.7	70.2	54.7	56.5	45.2	51.2	39	44.7
11.	46.0	46.5	50.5	46.2	51.2	44.0	48.0	69	52.2	56.5	46.2	51.2	37.7	44.0
12.	46.0	46.5	50.5	46.0	52.0	44.5	48.2	69.5	53.5	57	46	52	38.2	44.5
13.	45.7	45.7	49.7	45.7	51.0	44.5	47.7	70	61	58	45.7	51	38.7	45.1
14.	45.7	45.5	50.2	45.5	51.5	44.2	47.8	68.7	53	58.5	45.5	51.5	38.5	44.8
					@ Inlet Velocity of 20 m/s									
15.	46.0	47.5	51.7	46.2	52.7	45.2	49.0	71	68.5	60	46.2	52.7	38.7	45.68
16.	45.2	46.5	51.5	46.7	52.7	45.5	49.1	71.7	59.7	61	46.7	52.7	39.2	45.93
17.	46.2	46.0	52.0	46.7	53.0	45.7	49.3	72.2	58	60.5	46.7	53	39.2	45.93
18.	46.5	46.7	52.0	47.0	53.5	46.0	49.6	71.5	53.7	59.5	47	53.5	39.5	45.93
19.	46.7	47.5	52.7	48.0	53.7	47.0	50.3	70.5	53.5	58	48	53.7	40	45.68
20.	47.5	48.0	53.0	48.5	53.7	47.5	50.6	70.5	55	57	48.5	53.7	40	45.62
21.	48.2	48.5	53.5	48.5	54.0	48.0	51.0	69.7	56	59	48.5	54	40.2	46.18

Exhaust Gases		Hx Fluid		V in m/s	Re	Pr	Nu	h	cp exhaust	mass $\rho * A * V$	Q exhaust	cp fluid	U	Q fluid
Inlet	Out.	In	Out											
47.7	49.0	5	49	14	15573	0.720	279588	382336	1.005	0.02468634	1.09163	1.008	632	13.79352
49.2	49.0	5	49	14	15573	0.720	279588	382336	1.005	0.02468634	1.09163	1.008	632	8.759842
48.2	46.0	5	46	14	16000	0.723	511928	690846	1.005	0.02468634	1.0172	1.008	632	16.37506
47.7	45.7	5	46	14	16000	0.723	511928	690846	1.005	0.02468634	1.011	1.008	632	15.51885
48.0	45.5	5	45	14	16000	0.723	684541	923787	1.005	0.02468634	1.0048	18008	632	17.04213
47.7	45.2	5	45	14	16000	0.723	603187	814000	1.005	0.02468634	0.99859	1.008	632	16.98457
48.2	45.0	5	45	14	16000	0.723	858153	1158078	1.005	0.02468634	0.99239	1.008	632	19.18483
47.2	45.0	5	45	17	19429	0.723	1032774	1393728	1.005	0.02468634	0.99239	1.008	632	15.35233
49.7	45.2	5	45	17	19429	0.723	2651217	3577818	1.005	0.02468634	0.99859	1.008	632	22.87033
50.5	45.2	5	46	20	19429	0.723	3200930	4319654	1.005	0.02430792	0.98329	1.008	632	22.15328
50.5	46.2	5	46	17	19429	0.723	1962954	2649007	1.005	0.02430792	1.00772	1.008	632	23.1182
49.7	45.7	5	45	17	19429	0.723	1242272	1676446	1.005	0.02468634	1.011	1.008	632	22.27669
50.2	45.5	5	46	17	19429	0.723	998000	1346801	1.008	0.02430792	0.99235	1.008	632	21.49454
51.7	46.2	5	46	20	22857	0.723	479466	1346801	1.008	0.02430792	1.01072	1.008	632	24.54779
51.5	46.7	5	46	20	22857	0.723	503236	647040	1.008	0.02430792	1.02297	1.008	632	23.95817
52.0	46.7	5	47	20	22857	0.723	558624	679117	1.008	0.02430792	1.02297	1.008	632	24.67241
52.7	48.0	5	48	20	22857	0.723	591156	679117	1.008	0.02430792	1.0536	1.008	632	22.83028
53.0	48.5	5	48	20	22857	0.723	716302	797766	1.008	0.02430792	1.06585	1.008	632	23.67412
53.5	48.5	5	50	20	22857	0.723	716302	966651	1.008	0.02430792	1.06585	1.008	632	19.26686
copper tube outer dia = 6 mm; inner dia = 4 mm. length = 36 inches; no. of tubes = 2														

Stability tests of silver Nanoparticles

✓ After the addition of the silver nitrate solution to the sodium borohydride solution, half of the resulting solution was separated and partitioned into 5 test tubes (2 to 2.5 ml each) and labeled A through E.

✓ The solution contained in Tube A was not altered, in order to compare the changes occurred in the other tubes. This solution was denominated like standard solution of silver nanoparticles.

✓ After addition of the reagents to tubes B through E, color changes and / or precipitation of the system were noted.

✓ To tube B 5 drops of the 1.5 mol L $^{-1}$ NaCl solution were added . To the Tube C were added 5 drops of a 0.3% solution of PVP or PVA. The PVP and PVA stabilizer polymers were used in alternate day practices. Subsequently, the same amount of NaCl solution 1.5 mol L $^{-1}$ was added.

✓ To the D-tube was added a spatula tip of solid AgNO$_3$.

✓ To the Tube E, 1.0 x 10 $^{-3}$ mol L $^{-1}$ AgNO$_3$ solution was added dropwise , and in this way, it was possible to observe different steps of the nanoparticle aggregation process through the changes of the solutions. The solutions representative of different stages of aggregation of the nanoparticles were stored in different test tubes and their electronic spectra were obtained. Most groups have succeeded in this step, which must be done very carefully to get a "spectrum" of solution with several colors.

Comparative Analysis of Heat Transfer by Turbulence Promoters & Nano Fluids

Experiments are conducted in two stages viz. first stage using Turbulence promoters and in the second stage using Nano fluid in Heat Exchanger. In the first stage, two different experiments are performed varying the hot – cold fluid.
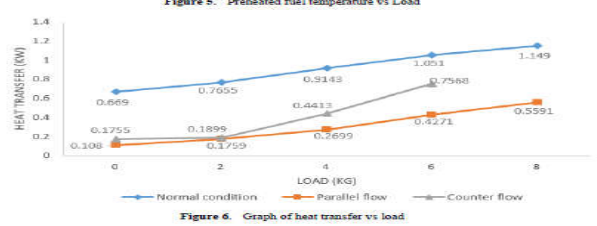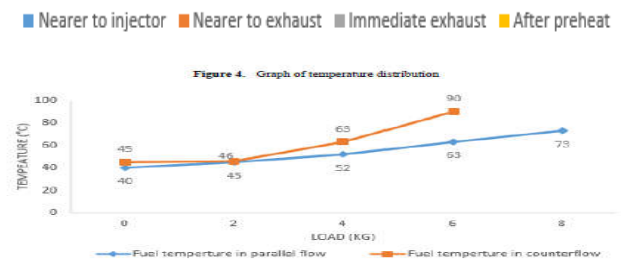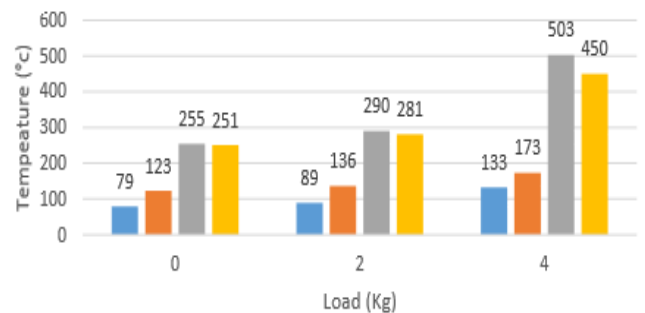
RESULTS AND DISCUSSION

The results obtained during preliminary test and main tests are presented here.

Along with this, an estimation of amount of waste heat recovered and the effectiveness is also done for both parallel and counter flow arrangements.

Results for Shell and Tube Heat Exchanger

Figure 5 shows temperature variation of preheated fuel with parallel and counter flow arrangement. The preheated fuel temperature at maximum load for parallel flow found to be 73°C and for counter flow is 90°C respectively. From the graph it is clear that counter flow heat exchanger is more effective than parallel.
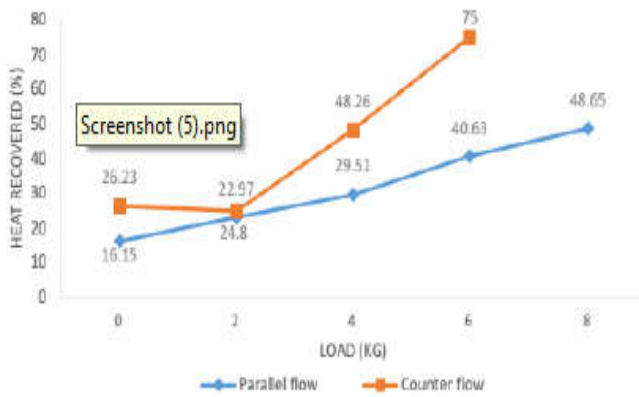

Figure 4.   Graph of temperature distribution

Figure 5.   Preheated fuel temperature vs Load

Figure 6.   Graph of heat transfer vs load

Figure 7. Percentage Heat Recovered vs load

Waste Heat Recovered

Since the objective is to determine waste heat recovery from the engine. Waste heat recovered is the ratio of heat absorbed by fuel (Qf) in the heat exchanger to the heat available in the exhaust gas (Qe) at the given load conditions. In figure 6, normal condition indicates heat available in the exhaust gas (Qe) and red lines indicates heat absorbed by the fuel for both parallel and counter flow arrangements. It is observed that at 4kg and 6 kg load heat absorbed by fuel is higher for counter flow heat exchanger. Figure 7 below shows heat recovered in percentages for both parallel and counter flow arrangements. It is found that waste heat recovered for counter flow is more than that for parallel flow at same loading. This is mainly due to higher fuel temperature achieved in counter flow heat exchanger for the same engine loading than parallel flow type. 75% heat is recovered in counter flow as against 40.63% in parallel flow type for 6 kg load at 1440 rpm.

CONCLUSION

In this work it is found that use of heat exchanger is a useful and simple method to utilize the waste heat energy available in the exhaust gas of diesel engine. Here shell and tube heat exchanger design is used with both counter and parallel flow arrangements. Following conclusion can be drawn from the experimental results:

- Fuel preheat temperature depends on flow rate of exhaust gases
- In shell and tube heat exchanger, fuel preheat temperature is from 40°C to 73°C for counter flow is from 45°C to 90°C for the loads ranging from 0kg to 8kg at 1440rpm by controlling mass flow rate of exhaust gas.
- Effectiveness of heat exchanger is calculated by considering full load conditions. It is found that effectiveness for parallel flow is 75% and for counter flow 81%.
- Waste heat recovered at 50% full load condition is found to be 48.5% for parallel flow and 72% for counter flow arrangements.
- Waste heat recovered for counter flow is more than that for parallel flow at same loading. Hence waste heat recovery is good in counter flow compared to parallel flow.

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