Experimentation of a Diesel Engine with Waste Heat Recovery Heat Exchanger

Sabarish Kumar P, Santhosh D, Arun Vasantha Geethan K , Arun Raja A K

Abstract: *In Rural Areas The Diesel Engine Generator Set Which Uses Diesel Engine Is Used For Irrigation And Agricultural Purposes. But Today The Cost Of Diesel Is Drastically Increasing And The Fossil Fuels Are Continuously Depleting. Also The Exhaust Gases Carry Away Around 35% Of The Total Heat Supplied To The Engine. Consequently Attempts Are Taken To Elevate The Propellant Economy And To Escalate The Productivity Of The Engine By Enhancing The Pursuance And Exudation Distinctive Of The Diesel Engine. Hence A Waste Heat Recovery Exchanger Was Modeled And Synthesized To Utilize The Heat From Exhaust Gases To Preheat The Incoming Air Before Supplying It Into The Cylinder Of The Engine. Initially The Pursuance And Exudation Distinctive Of The Diesel Engine Were Carried Out Without The Heat Exchanger. Then The Same Experiments Were Carried Out With The Heat Exchanger And The Results Reveals That There Is An Improvement In The Performance And Reduction In Emissions Of The Diesel Engine.*

Keywords: *Diesel Engine; Waste Heat Recovery; Heat Exchanger; Preheating; Exhaust Gases*

I. INTRODUCTION

The major problem that the world is currently facing is the energy crisis. We are still depending upon the fossil fuels to produce electricity and for transportation purposes, even though the cost of these fossil fuels are continuously increasing and these fossil fuels are depleting as days progresses. Also there are some environmental issues like global warming, ozone layer depletion and the atmospheric air gets polluted because of drastic increase in usage of automobiles. Another major problem associated with the internal combustion engine is only 35% of the total heat energy supplied by burning the fuel is converted into useful mechanical power. And the remaining is rejected as waste into the atmosphere. Therefore efforts must be taken to improve the fuel economy, to reduce the exhaust emissions from the diesel engine and to increase its efficiency. In order to reduce the usage of diesel biofuels gained more attention and many researches are available regarding the performance and emission analysis of diesel engine using biodiesel. But we need to modify the design of the engine in order to use biodiesel as the fuel instead of using the conventional fuel diesel.

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* Correspondence Author

Sabarish Kumar P*, Department of Mechanical Engineering, St.Joseph's Institute of Technology, OMR, Chennai 119. *pskgps@gmail.com

Santhosh D, Department of Mechanical Engineering, St.Joseph's Institute of Technology, OMR, Chennai 119. *pskgps@gmail.com

Arun Vasantha Geethan K , Department of Mechanical Engineering, St.Joseph's Institute of Technology, OMR, Chennai 119. *pskgps@gmail.com

Arun Raja A K , Department of Mechanical Engineering, St.Joseph's Institute of Technology, OMR, Chennai 119. *pskgps@gmail.com

Sabarish et al. conducted an experiment a diesel engine and found that there was an increase in emission of nitrogen oxide due to usage of pongamia methyl ester as the biodiesel [1]. Therefore oxidation inhibitor was used along with the biodiesel in order to reduce the nitrogen oxide emission since increased nitrogen oxide emission is due to excess oxygen availability in the biodiesel [2]. Sabarish et al. conducted an experiment in low heat rejection engine and recorded an increment in productivity and reduction in fuel depletion and exudation from the diesel engine [3]. Gopinathan et al. premeditated the aftereffect of carbon nano tubes in pursuance and exudation characteristics of the diesel engine [4]. There was a drastic increase in nitrogen oxide exudation if the engine cylinder temperature exceeds 1800 K [5]. It is suggested to use organic Rankine cycle to improve the efficiency of the internal combustion engine [6]. If the Direct Injection Diesel engine is reformed to work on binary mode with and without diesel vapor concoction, it leads to tremendous reduction of nitrogen oxide emission [7-8]. Novel methods like placing a heat exchanger to preheat the air leads to increase in efficiency of the engine [9]. Altering injection pressure also has an impact over the pursuance and exudation of the diesel engine [10]. In order to reduce the emission of nitrogen oxide exhaust gas recirculation (EGR), method has been adopted to control the peak temperature of the cylinder [11]. The temperature of the incoming air after preheating using waste heat recovery heat exchanger is optimum at 150°C which reduces the smoke level of the diesel engine [12].

Therefore in this study a waste heat recovery heat exchanger of counter flow shell and tube type is employed to preheat the incoming air up to 150°C and then the pursuance and exudation distinctive of the diesel engine is to be evaluated.

II. DESIGN OF HEAT EXCHANGER

Hot fluid in the heat exchanger – Exhaust gas
Cold fluid in the heat exchanger – Air
Entry febricity of warm fluid T_1 = 600°C
Entry febricity of frosty fluid t_1 = 33°C
Exit febricity of frosty fluid t_2 = 150°C
Mass extinction of warm fluid m_h = 1 kg/sec
Mass extinction of warm fluid m_c = 1 kg/sec
Specific heat capacity of hot fluid Cp_h=1.063 KJ/kg k
Specific heat capacity of hot fluid Cp_c = 1 KJ/kg k
Overall heat transfer coefficient U = 600 W/m^2 K

$$Q = m_c * Cp_c * (t_2 - t_1)$$
$$= 1 * 1 * (150-33)$$
$$= 117 \text{ KW}$$

$m_h * Cp_h * (T_1 – T_2) = 117$
$1 * 1.063 * (600 – T_2) = 117$
$T_2 = 489.93°C$

$LMTD = [(T_1 - t_2) - (T_2 – t_1)] / \ln [(T_1 - t_2) / (T_2 – t_1)]$
$= 24°C$
Also $Q = U * A * LMTD$
$A = Q / (U * LMTD)$
$= 117 * 1000 / 600*24$
$= 8.125 m^2$.
Effectiveness of the heat exchanger,
$£ = [(T_1 – T_2) / (T_1 - t_1)]$
$= [(600 – 489.93) / (600 – 33)]$
$= 0.66$

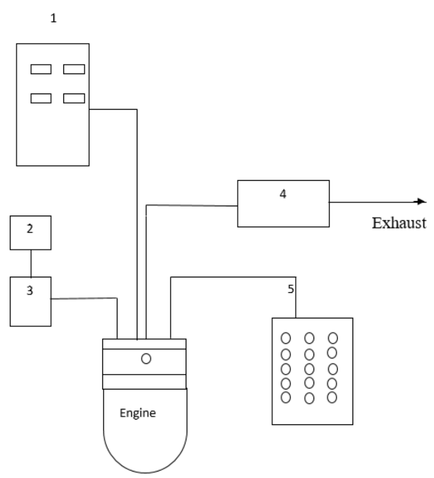
III. EXPERIMENTAL SETUP

The current examination is executed in a single cylinder four stroke engine which is vertically placed and cooled with the help of air. The injection pressure of the engine was 200 bars. The elaborated stipulation of the engine is conferred in the table 1. The volume of the engine was 661 cm^3.

Table 1 Stipulation of the engine

S.No	Type	Single cylinder, Air cooled, Vertically placed, Four Stroke Engine
1	Engine Potential	4.5 KW
2	Cylinder Diameter (D)	85 mm
3	Cylinder Length (L)	110mm
4	Compression Ratio	16.5:1
5	Pressure of fuel injection	195 bars
6	Capacity of the engine	661 cm^3

For applying variable loads the engine was coupled with eddy current dynamometer. The AVL 444 Di-gas investigators were utilized to evaluate the exudation of carbon monoxide, hydrocarbon and nitrogen oxide. AVL combustion data acquisition system was used to determine the agitation parameters such as degree of heat exoneration and cylinder pressure. The experiential setup is shown in the fig. 1.



1. Control panel
2. Fuel tank
3. Fuel flow meter
4. AVL Digas 444 analyser
5. Electrical loading using DC generator

Fig. 1 Experiential setup

IV. RESULTS AND DISCUSSION

4.1 PERFORMANCE CHARACTERISTICS

The most important pursuance distinctive of the engine that are to be discriminated between the engine operated without heat exchanger and the same engine operated with the heat exchanger are brake thermal efficiency as well as the specific fuel consumption

4.1.1 BRAKE THERMAL EFFICIENCY

Brake thermal efficiency connotes how efficaciously the thermal energy furnished by the fuel is transformed into advantageous mechanical effort. Fig.2 reveals the exemplification of brake thermal efficiency of the engine operated with and without the heat exchanger. The engine operated with the waste heat recovery heat exchanger operates with more productivity than the engine without the heat exchanger. It is observed that the brake thermal efficiency increased by 12.5% when the engine is operated with the heat exchanger. It is because of the increased suction temperature of the air due to preheating.

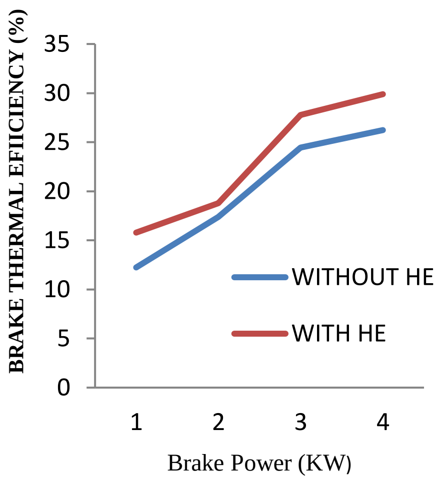


Fig. 2 Comparison of Brake thermal efficiency

4.1.2 BRAKE SPECIFIC FUEL CONSUMPTION

The quantity of fuel utilized by the engine in one second to develop one kilo-watt of power is defined as the brake specific fuel consumption. It is a significant criterion that illustrates the pursuance of the engine. It is contrarily proportional to the thermal efficacy of the engine. The discrimination of fuel consumption operated with and without the heat exchanger is shown in the fig. 3.

From the fig. we can easily realize that the specific fuel consumption is lower when the engine is operated with the heat exchanger. When the engine is operated with the heat exchanger the consumption of fuel reduces by about 18.6%.

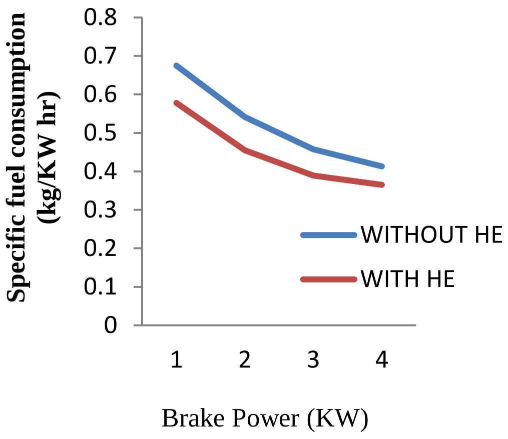


Fig. 3 Comparison of Specific fuel consumption

4.2 EMISSION CHARACTERISTICS

Emission of hydrocarbon, carbon monoxide and nitrogen oxide are various emission characteristics which are to be compared between the engine operated without heat exchanger and the same engine operated with the heat exchanger.

4.2.1 EMISSION OF CARBON MONOXIDE

Carbon monoxide ejection from the engine is the due to meager oxygen availability in the air fuel confection. The level of carbon monoxide that has been discharged from the engine is 16:1 which cannot be ignored even in scanty fuel concentration. Carbon monoxide discharge in association with the brake power when the engine is operates with and without the heat exchanger has been conferred in the fig.4. It is apparent from the fig. that the carbon monoxide exudation is found to be lower in the engine operated with the heat exchanger. When the engine is operated with the heat exchanger the emission of carbon monoxide reduces by about 6.9%.

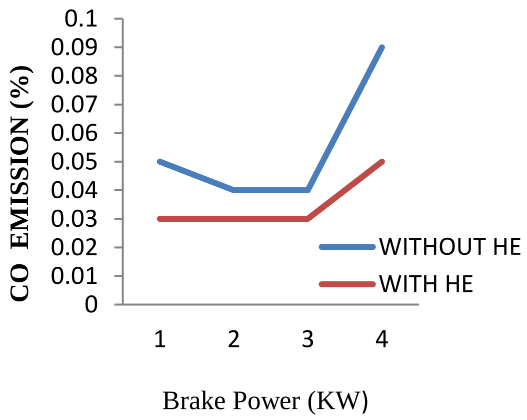


Fig. 4 Comparison of Carbon monoxide emission

4.2.2 EMISSION OF HYDROCARBON

The exudation of unburnt hydrocarbon is the outcome of imperfect combustion. The criteria that have an impact over the discharge of hydrocarbon are improper combustion chamber modeling, high fuel intake. Unburnt hydrocarbon discharge in association with the brake power when the engine is operates with and without the heat exchanger has been conferred in the fig.5. It is apparent from the fig. that the hydrocarbon exudation is found to be lower in the engine operated with the heat exchanger. When the engine is operated with the heat exchanger the emission of hydrocarbon reduces by about 24.66%.

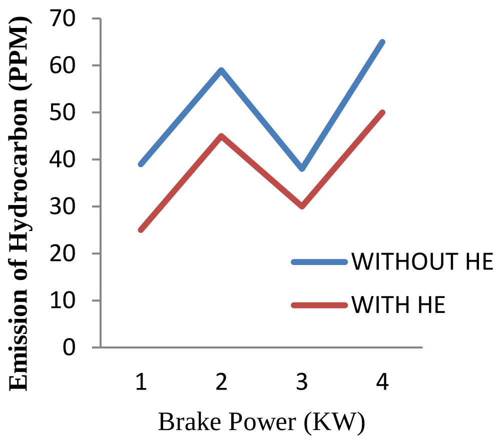


Fig. 5 Comparison of hydrocarbon emission

4.2.3 EMISSION OF NITROGEN OXIDE

The most consumptive exudation from the engine exhaust is the nitrogen oxide. The major reasons for the emanation of nitrogen oxide are fuel with greater oxygen content and higher engine cylinder temperature. Nitrogen oxide discharge in association with the brake power when the engine is operates with and without the heat exchanger has been conferred in the fig.6. It is apparent from the fig. that the exudation of nitrogen oxide is found to be lower in the engine operated with the heat exchanger. When the engine is operated with the heat exchanger the nitrogen oxide exudation reduces by about 15.5%.

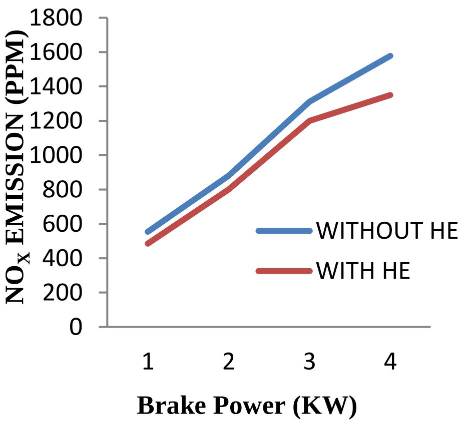


Fig. 6 Comparison of nitrogen oxide emission

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V. CONCLUSION

Waste heat recovery heat exchanger specially designed for preheating the fresh incoming air by utilizing the waste heat from the exhaust gases tend to be very useful in running the diesel engine by preheating the air to 150°C. The brake thermal efficiency of the engine tends to increase when operated with the heat exchanger. Meanwhile the specific fuel consumption, emission of hydrocarbon, carbon monoxide and nitrogen oxide has been decreased due to the heat exchanger.

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AUTHORS PROFILE

P. Sabarish Kumar, currently working as Assistant Professor at St. Joseph's Institute of Technology, obtained his B.E. degree in Mechanical Engineering in the year 2012 from Kongu Engineering College, Erode, M.E. degree in Thermal Engineering in the year 2015 from Regional Centre of Anna University, Tirunelveli. Currently pursuing Ph.D. degree in SRM University, Chennai. He has published 6 Scopus Indexed journals.

D. Santhosh, currently working as Assistant Professor at St.Joseph's Institute of Technology, obtained his B.E. degree in Mechanical Engineering in the year 2015 from St.Joseph's Institute of Technology, M.E. degree in Manufacturing Technology in the year 2017 from St.Joseph's College of Engineering, Chennai.

Dr.K.Arun Vasantha Geethan, Professor and Head of Mechanical Department, obtained his M.E degree in CAD / CAM in the year 2004 from Govt. College of Engineering, Tirunelveli and got his Ph.D., from Sathyabama University, Chennai.

A.K.Arun Raja, currently working as Assistant Professor at St.Joseph's Institute of Technology, obtained his B.E. degree in Mechanical Engineering in the year 2010 from St.Joseph's College of Engineering, Chennai, M.E degree in CAD / CAM from Central Institute of Plastics Engineering and Technology in the year 2012, pursuing Ph.D. in Sathyabama University, Chennai.