Analysis of Waste Heat Recovery by Using Neem Biodiesel blend

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Abstract: The increasing demand for power has led to considerable fossil fuels burning which has in turn had an adverse impact on environment. It is seen that approximately, 30 to 40% of heat is only converted into useful mechanical work and the remaining heat is emitted into atmosphere as waste heat. Efficient use of energy and its conservation assumes even greater importance in view of the fact that one unit of energy saved at the consumption level reduces the need for fresh capacity creation by 2.5 times to 3 times. The economic development of a country is often closely linked to its consumption of energy. Although India ranks sixth in the world as far as total energy consumption is concerned, it still needs much more energy to keep pace with its development objectives. It can be seen that there is growing momentum behind energy recovery innovation among legislative leaders at the local, state and federal level. Energy recovery includes any process that converts waste material into energy. The Recovery technique reduces the amount of waste heat being emitted into the atmosphere. This paper shows the availability and possibility of waste heat from internal combustion engine using Matrix Heat Exchanger and Neem Biodiesel blend, also describe loss of exhaust heat energy as waste heat. Waste heat recovery system leaves a pathway for recycling and conserving fuel for future generations.

Keywords: Matrix heat exchanger, Esterified neem biodiesel blend, Waste heat recovery, Normal diesel engine, Neem oil.

I. INTRODUCTION

Waste heat is the heat, which is generated in the process of combustion of fuel in the Internal Combustion Engine. Exhaust gas immediately leaving the engine can have temperatures as high as [450°C-600°C].

Waste heat is by necessity emitted by IC engines in the form of exhaust and cooling systems. Heat Transfer is a process by which internal energy from one substance transfers to another substance. There are three modes of heat transfer namely, Conduction, Convection and Radiation. Heat transfer can be made through Heat Exchanger. Heat Exchanger is a device built for efficient heat transfer from one medium to another. Here in this paper were using Matrix Heat Exchanger and Neem Biodiesel blend for the recovery of waste heat through exhaust by heat transfer process.

II. LITERATURE REVIEW

Venkatarathnam (1990), gave a chronological development of the matrix heat exchanger for cryogenic applications covering four decades, from when the matrix heat exchanger was first introduced by McMohan in 1949, until late 1990. They surveyed different methods of fabrication, heat transfer and fluid flow characteristic, and design and simulation procedures. They concluded that better correlations should emerge, and recommended that attempts should be made to predict heat transfer and flow friction performance from fundamental relations on different heat transfer mechanisms, which will result in optimized geometries and operating conditions.

Suthar Dinesh Kumar et al The characteristic of the neem oil and bio diesel blend was analyzed by varying the ratio of bio diesel and neem oil was presented by Sunthar Dinesh Kumar L, Dr.Rathod Pravin P, Prof.PatelNikul K. He analyzed the calorific value of the bio diesel and neem oil blend and compared with the diesel. He concluded that the lower calorific value of neem oil biodiesel is mainly due to oxygen content of neem oil bio diesel and increases brake specific fuel consumption compared to diesel. The maximum power produced using neem oil bio diesel is less compared to diesel because of calorific value.1

Husain et al, Only a part of the energy released from the fuel during combustion is converted to useful work in an engine. The remaining energy is wasted and the exhaust stream is a dominant source of the overall wasted energy. There is renewed interest in the conversion of this energy to increase the fuel efficiency of vehicles. There are several ways this can be accomplished. This work involves the utilization thermoelectric (TE) materials which have the capability to convert heat directly into electricity. Thus the various possible exhaust heat recovery methods have been discussed by Husain Q, Brigham D, Maranville C in Thermoelectric Exhaust Heat Recovery for hybrid vehicles.

Pandiyarajan et al, Approximately, 30 to 40% of the heat generated in the fuel combustion process is converted into useful mechanical work in contemporary internal combustion engines (Wojciechowski et al., 2010). The remaining heat is emitted to the environment through exhaust gases and engine cooling systems, resulting in an enormous waste of energy and the serious environmental pollution. Pandiyarajan and others have studied experimentally how to recover exhaust gas WH of automobile (Pandiyarajan et al., 2011) and designed a finned tube heat exchanger and a heat storage system (Gunerhan and Hepbasli, 2005).

Mostafavi and Agnew et al have calculated the rate of WH recovery of supercharged engine exhaust (Mostafavi and Gnew, 1997). Aly (1988), have studied the comprehensive applications of exhaust gas recycling and circulating cooling water WH recovery of internal combustion engine (Aly, 1988). Koehler et al. (1997) designed a refrigerator system of truck engine exhaust WH (Koehler et al., 1997), with which can replace the conventional compression refrigerator system (Yousef and Najjar, 1996).

Horuz(1999) experimental research exposes that it is feasible to drive refrigeration system with automobile engine exhaust WH (Horuz, 1999). (Manzela et al., 2010) studied ammonia water absorption refrigeration system with automobile engine exhaust WH drive, and analysed its economic feasibility.

Hilalil and Soylemez (2008)revised the structure of the vehicle exhaust-driven refrigeration system, and conducted optimized calculation of its WH recovery rate and operational economical efficiency. Wu and Shulden (1995) studied improved carnot-cycle heat engine driven by high-temperature WH (Wu and Schulden, 1995) and found the relation of a temperature range of high-temperature WH and the maximum specific power. Jung-In (Yoon et al., 2003) studied the exhaust WH driven refrigeration system.

Teng et al., 2011,The waste heat rejected through the exhaust represents a large fraction of the fuel's energy (Talyor, 2008). Several modern diesel engines are equipped with exhaust gas recirculation (EGR) to control NOx emissions. High EGR rates require effective cooling of recirculated gas. This heat rejection has a temperature level suitable for an effective WHR system. Suitable bottoming cycles for diesel and gas engine are the Rankine, Brayton, Kalina, and Stirling cycles (Korobisyn 1998).**Chen (2011)** states that the Kalina cycle performs substantially better than a steam Rankine cycle. The Kalina cycle can produce 10-30% more power than a steam Rankine cycle. Another advantage is the smaller size of the whole unit. The footprint of the Kalina plant is about 60% of the size of a steam Rankine plant design. (Korobitsyn 1998; Poullikkas 2005).

Chen et al, The Trilateral Flash Cycle is a thermodynamic power cycle whose expansion starts from the saturated liquid state rather than a vapor phase. By avoiding the boiling part, the heat transfer from a heat source to a liquid working fluid is achieved with almost perfect temperature matching. The second feature comes from the use of the ammonia-water mixture that offers a better match with the temperature profiles in the heat sink. Its power recovery potential is highly dependent on the efficiency of the two-phase expansion process. (Chen 2011; Zamfirescu&Dincer 2008).

Bombarda et al. (2010) compared the thermodynamic performance of the Kalina cycle and ORC (hexamethyldisiloxane as working fluid) in the case of heat recovery from two Wartsils 20v32 8.9 MW diesel with exhaust gas mass flow of 35kg/s for both engines, at 346°c. In order to facilitate the comparison, only the heat recovery from the exhaust gases was considered. An almost equal net electric power of 1615 KW (with a cycle efficiency of 19.7%) and of 1603 KW (with cycle efficiency of 21.5%) for the Kalina cycle requires a very high maximum pressure in order to obtain high thermodynamic performances: 100bar against the about 10bar of the ORC cycle. The use of the Kalina cycle for medium and high temperature thermal sources seems unjustified because there is no gain in performance instead, a complicated plant scheme, large surface heat exchangers and corrosion resistant materials, such as titanium in the turbine, result.

Vlaskos et al. (2010) have demonstrated the stirling engine cycle as a bottoming cycle for a diesel engine. A hypothetical 5000KW diesel engine was assumed to compare different options for exhaust heat recovery, 12- and 16-cylinder, low speed stirling engines were examined. The simulation with the 16-cylinder, 721 version showed the following characteristics: shaft power 740 KW (600rpm) overall efficiency 27. This exhaust steam is condensed (liquid) water when used a heat source for a waste heat recovery system. This condensed water is pumped to a boiler , where it is evaporated and superheated, and is used to produce power in a steam expander. A classical locomotive steam engine is an example of an open Rankine cycle. (Yamada & Mohamad 2010).

Brands, et al. [18] achieved WHR in a six cylinder, 14.5 L, Cummins NTC-400 diesel engine rated at 298KW at 2100rpm by turbo-compounding. This involved the use of a power turbine to recover energy from the exhaust gas. The authors demonstrated a 12.5% improvement in power and 14.8% net improvement in fuel economy due to WHR by Rankine cycle turbo-compounding.

Vaja, et al. [23] Stationary IC engines were investigated by for WHR using a thermodynamic analysis. They predicted a 12% improvement in thermal efficiency. Various working fluids were tested and benzene showed the highest improvement. A critical heat exchanger was needed to be designed in their analysis to achieve the predicted results.

Teng, et al. [22] analysed a super critical ORC system of WHR from heavy duty diesel engines. The exhaust WHR was analysed from the perspectives of the first and second law of thermodynamics. They predicted up to a 20% improvement in engine power using a super critical ORC.

Chen, et al. reviewed many methods incorporated by various investigators to improve engine efficiency. They came to the conclusion of a possible multi-stage Rankine cycle with the 1st stage operating on water followed by a 2nd stage operating on R-11 (organic solvent) to recover high temperature exhaust heat and to enable low temperature exhaust WHR respectively. They also predicted a 15% improvement through WHR.

Garimella and co-workers have explored and developed a variety of compact heat exchanger geometries for use in absorption systems (Garimella, 2000; Meacham and Garimella 2002, 2003, 2004; Determan and Garimella, 2011; Garimella et al., 2011; Nagavarapu and Garimella, 2011; Determan and Garimella, 2012). They have focused n the design, fabrication and demonstration of compact absorber and desorber components for falling-film configurations and have also developed an entire monolithic miniaturized absorption system with micro channel convective flow components.

In 2009, Dai et al. studied the effect of using different fluids on the heat recovery Rankine cycle and optimized the thermodynamic parameters like energy efficiency for the studied working fluids. Vaja and Gambarotta studied the effect of various working fluids on the efficiency of Rankine cycle used for waste heat recovery.

Srinivasan et al. examined the exhaust waste heat recovery potential of a high efficiency, low-emissions dual fuel low temperature combustion engine using an ORC. In this study, the various waste heat resources were investigated in a 12-liter compression ignition engine then, two different configurations of Rankine cycle were introduced for simultaneous heat recovery from the studied engine coolant and exhaust gases. Preheat and Two-stage configurations. A parametric optimization process was considered for each configurations.

In 2010 Farzaneh-gord et al. investigated heat recovery from a 1.7 L natural gas powered internal combustion by co2 trans critical power cycle. Many researchers have been performed about using different working fluids, different configurations of Rankine cycle, and improving the system components during the recent years.

From this literature review concluded that the Biodiesel and matrix heat exchangers were used to increase the thermal efficiency and also reduce emission come out from the IC engines.

III. EXPERIMENTAL SETUP:

3.1 DESIGN MODEL:

The design model of the waste heat recovery system is shown in Figure.1 It consists of following parts,

- Fuel supply unit
- Matrix heat exchanger
- IC engine

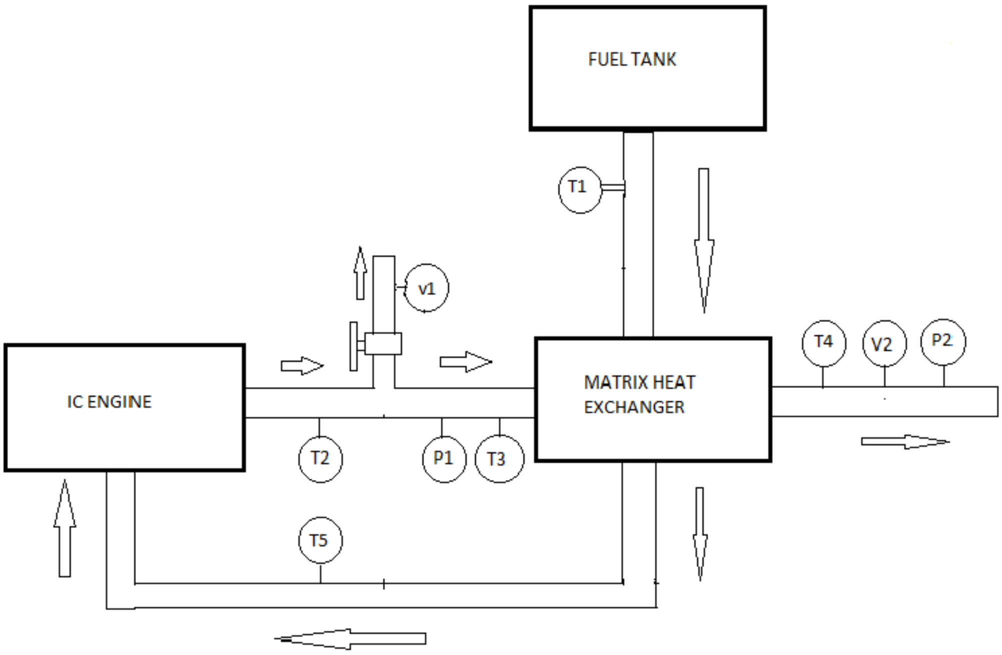

Figure.1.design model of the waste heat recovery by using Matrix Heat Exchanger (MMHE)

3.2 Neem Oil:

Neem oil is a vegetable oil pressed from the fruits and seeds of the Neem tree. Neem oil is in golden yellow, yellowish brown, reddish brown, dark brown, greenish brown or bright red. It has a strong odour. It is composed mainly of triglyceride and triterpenoid compounds that are responsible for the bitter taste. It is hydrophobic in nature.

3.3 Preparation of biodiesel:

Oil samples with beaker were kept on hotbox oven chamber. Amongst all the samples we take one as the most satisfactory result. The sample of 100 ml of Neem oil with 300 ml of methanol (CH_3OH) in presence of NaOH (8 gms) as catalyst was taken as final production of Esterified neem oil. The amount of Esterified neem oil was 0.350 ml. The viscosity of the oil was measured with the help of Say bolt Viscometer. The density and calorific value were measured with the help of Electronic Precision Balance and Bomb Calorimeter respectively in the Heat Engine Laboratory. In the following table1 describes the properties of neem oil . The different fuel physico- chemical were observed from the ITA Lab,Chennai.

Table 1. The observed properties

Properties	**Neem oil**	**Esterified Neem oil***	**Bio diesel***
Density (gm/cc)	.878	.772	.82
Kinematic viscosity (centistokes) at 35ºC of oil	24.14	21.40	4.0
Calorific value[MJ/kg]	26.65	-	43

Flash point	180°C	140°C	110°C
Fire point	210°C	170°C	130°C

3.4 Engine Specification:

The experiments were conducted on a Kirloskar made four stroke single cylinder water cooled direct inject compression ignition engine without any hardware modifications. The conventional type of diesel were used in diesel engine and emits a lot of pollutants and it will be wiped out in future, so that the Esterified Neem biodiesel blends (B10, B20, B30, B40, and B50) is used. Diesel and Biodiesel was used to test a conventional engine and also aided with matrix heat exchanger at different loads. Performance parameters like brake power, specific fuel consumption and brake thermal efficiency were evaluated.

Table 2.Specifications of an IC engine

Type	**Kirloskar**
Details	Single cylinder, four stroke, water cooled
Bore & Stroke	80×110 mm
Rated Power	3.75 KW at 1500 rpm
Compression ratio	17:1

3.5 WORKING PRINCIPLE

Matrix heat exchanger (MHE) contains large number of identical tube passages. The set of tube channels are arranged to adapt to the flow of fluid in counter flow direction. The matrix density ratio of heat exchanger is 6600kg/m^3. The rectangular cross section of each tube is 2x2 cm and length is equal to 25cm. The hot gases are passed through the tubes of the MHE and increase the temperature of the cold fluid which flows in semi elliptical tube. Here the restrictions of the hot fluid are totally neglected. Because the semi elliptical profile will support the deviation phenomenon. Therefore free flow of the hot fluid is achieved in tube passage of MHE. Since the heat exchanger was placed in the exhaust manifold of the engine. The hot gases of IC are passed to heat exchanger on alternate chamber containing the working fluid. The matrix heat exchanger here is used to pre-heat the biodiesel blends. The heat transfer takes place between the exhaust gas unit and matrix heat exchanger, which decreases the viscosity of the working fluid.

IV. RESULT AND ANALYSIS:

4.1 Brake thermal efficiency:

Figure 2 and Figure 3 shows the variation in brake thermal efficiency for diesel & Biodiesel, When blends are used 20%, 30%, 40% and 50% in diesel engine. The brake thermal efficiency of biodiesel is decreased with increase in load for all the test fuels. The Brake Thermal Efficiency (BTE) of biodiesel decrease with an increase in amount of Esterified neem in the blends.

The performance of single cylinder four stroke diesel engine fuelled with bio diesel is investigated and the key results are summarized as below:

- The fuel properties of Biodiesel have a relatively greater flash point (110°C) that makes it less volatile and gives far better transportation than diesel fuel.
- The brake thermal efficiency of Biodiesel is lower than that of diesel for all engine brake loads. It is concluded that the Biodiesel ,i.e.,10N90D,20N80D,30N70D,40N60D and 50N50D are running normal during testing of diesel engine in normal diesel engine and matrix heat exchanger in diesel engine. 10N90D (10% of esterified neem oil and 90% of diesel) showed very close performance to that of diesel fuel, in normal diesel engine but in matrix heat exchanger used diesel engine 10N90D and 20N80D are closed performance to that of diesel engine .

Therefore, from the above analysis it can be concluded that the Biodiesel showed poor engine performance in comparison to Diesel fuel. Biodiesel can be used as a substitute fuel for Conventional petro-diesel in future

4.1.1Load in % vs Brake thermal efficiency in %

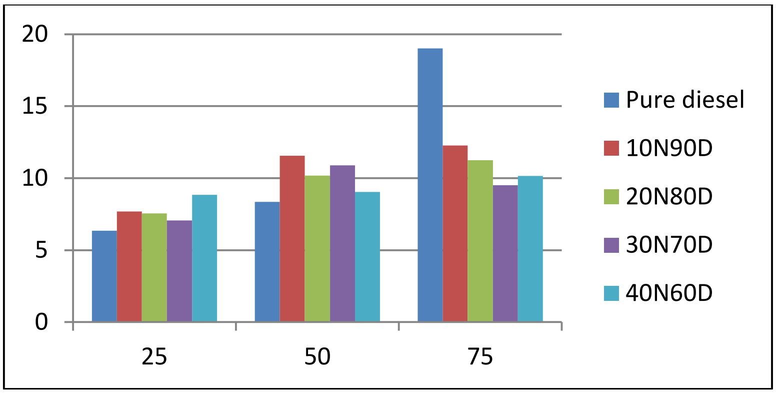

Figure 2 comparison chart for engine performance with Biodiesel and Diesel in Normal Diesel Engine (NDE)

4.1.2 Load in % vs brake thermal efficiency in%

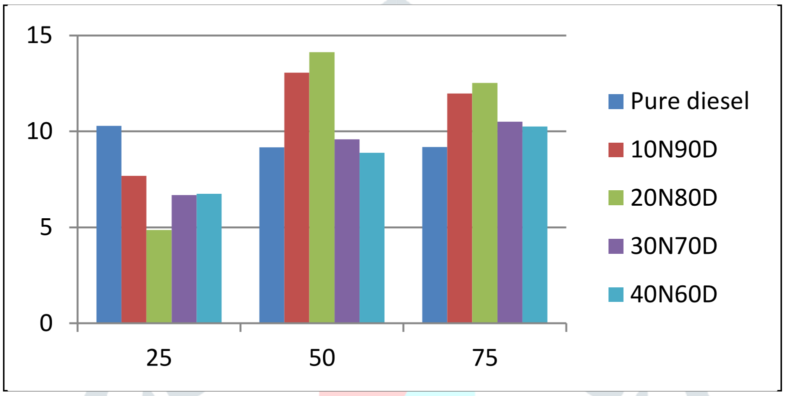

Figure 3 comparison chart for engine performance with Biodiesel and Diesel in Matrix heat exchanger in diesel engine (MHEDE).

4.2 Heat transfer:

Figure 4 and figure 5 shows the variation in heat transfer rate for diesel & Biodiesel, When blends are used 20%, 30%, 40% and 50% in diesel engine. The heat transferred between Biodiesel and the exhaust gas is increased with increase in load for all the test fuels. The heat transfer rate between Biodiesel and exhaust gas increases with an increase in amount of esterified neem in the blends in matrix heat exchanger in diesel engine as compared to normal diesel engine.

4.2.1 Load in % vs Heat transferred in W

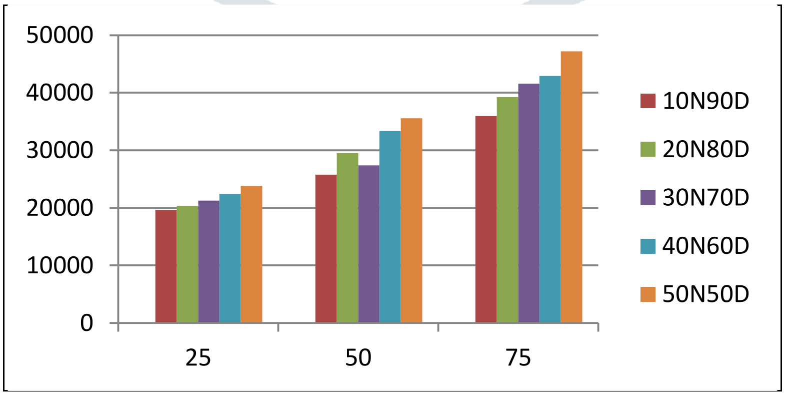

Figure 4 comparison chart for heat transfer rate Biodiesel in NDE

4.2.2 Load in % vs Heat transferred in W

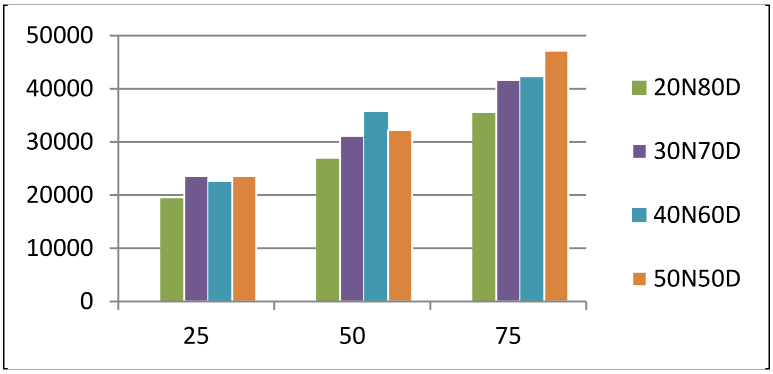

Figure 5 comparison chart for heat transfer rate with Biodiesel in MHEDE

4.3 Fuel consumption (fc):

When comparison with heat transfer rate and brake thermal efficiency, the matrix heat exchanger have better than normal diesel engine. So here matrix heat exchanger is taken into account for fuel consumption and also for further results. There will be variation in fuel consumption for diesel and Biodiesel when blends are used (10% 20%, 30% and 50%) in diesel engine. As the loads are increased the fuel consumption of diesel engine increases when compared with diesel fuel. At the constant speed of 1500 rpm and 0, 5, 10, and15 kg engine load, the fuel consumption of Biodiesel is increased than that of diesel fuel when the blends are used in diesel engine (10N90D, 20N80D, 30N70D, 40N60D and 50N50D respectively). It is observed that for the same load conditions the normal diesel engine consume more fuel when compared to matrix heat exchanger in diesel engine.

4.3.1 % of Blend vs Mass flow rate, kg/hr

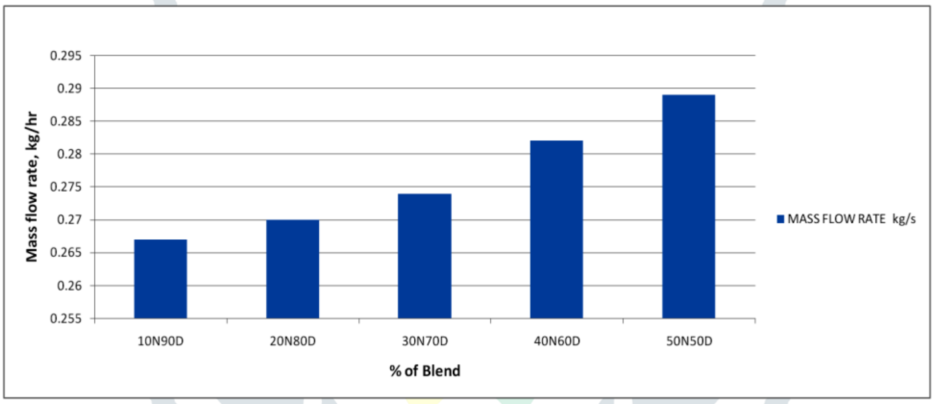

Figure 6 chart for mass flow rate with Biodiesel

4.4 Nusselt number vs Mass flow rate, kg/hr

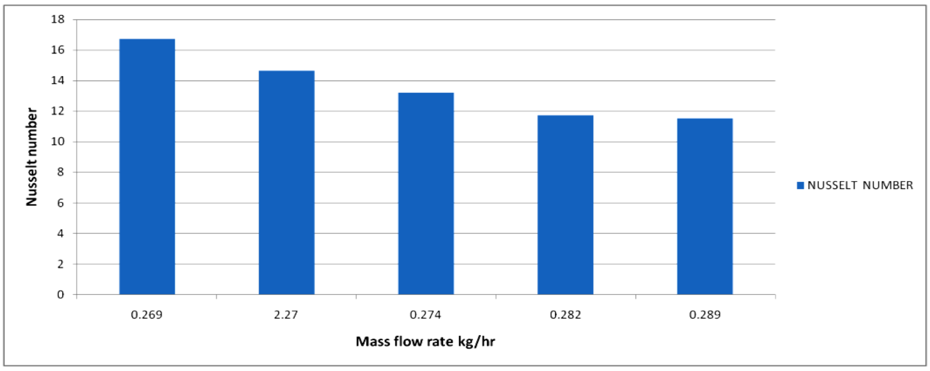

Figure 7 comparison chart for mass flow rate with Nusselt number.

4.5 Reynolds number:

The above figure 6 and figure 7 shows the variation of the Reynolds number with respect to the mass flow rate of the Biodiesel and Nusselt number in the matrix heat exchanger .It shows that the flow is turbulent and the Reynolds number decreases when the percentage of the esterified neem oil in the blend increases. Hence the Reynolds number depends on the viscosity, velocity, density of the fluid and the length of the pipe.

V.CONCLUSION:

It has been identified that there are large potentials of energy savings through the waste heat recovery technologies. Waste heat recovery defines capturing and reusing the waste heat from internal combustion engine for heating, generating mechanical or electrical work and refrigeration system. Waste heat recovery and Biodiesel in engine would also help to recognize the improvement in performance of the engine. If these technologies were adopted by the automotive manufacturers then it will result in greater efficiency in engine performance and lower emission. For waste heat recovery matrix heat exchanger is used, which has high efficiency, compared to normal diesel engine. The pure diesel and biodiesel used in normal diesel engine has lower brake thermal efficiency, heat transfer rate when compared to matrix heat exchanger used in diesel engine. If matrix heat exchanger is used in diesel engine in future, it reduces the emission that comes out from diesel engine because here the fuel is preheated before entering in to the combustion chamber. The alternate fuel neem biodiesel have been used here to reduce the conventional fuel usage and improve the performance of the engine.

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