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Utilisation of Heat Energy from The Exhaust Gases And Performance Analysis of a Diesel Engine, with Used Sunflower Oil-Diesel Blends

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Abstract: *The vegetable oils stands as an alternate fuels as physical and combustion properties are close to the diesel fuel. However the viscosity of the vegetable oils is higher than the diesel. In the present work waste sunflower oil is taken as an alternate fuel. The high viscosity of sunflower oil is decreased by blending with diesel in various proportions and heated prior to the combustion in the cylinder. The fuel blends are heated by means of the exhaust gases of the engine. The blends of varying proportions of sunflower oil and diesel are prepared, analyzed compared with diesel. The effect of temperature on viscosity of the fuel blends is also studied. The performance of the engine using fuel blends is evaluated in a single cylinder C.I engine and compared with the performance obtained with the pure diesel. The experiments are performed on the 4-stroke engine at various loads by maintaining constant speed.*

The performance parameters of the blends like brake specific fuel consumption, thermal efficiencies is observed very nearer values to the pure diesel values. The fuel consumption, thermal efficiencies are observed very nearer values to the pure diesel values. The fuel consumption and exhaust gas temperature are increased slightly for the fuel blends compared to pure diesel. The fuel blends supplied to the engine are S10 (10% sunflower oil and 90% diesel), S25 and S50, S60. It is observed that the performance of the engine is almost same up to S25 fuel blend without much heating, compared to pure diesel. The maximum brake thermal efficiency obtained is 30.3% for S 25 blend while it is 32.6% for pure diesel. The bsfc and maximum exhaust gas temperature obtained are 0.262 kg/kwh and 292^{0}C respectively for S 25 fuel blend, while they are 0.248 kg/kwh and 242^{0}C for pure diesel. Acceptable thermal efficiency and bsfc are also obtained for S 50 fuel blend.

Keywords – *Sun Flower oil, Diesel engine, fuel blends*

Introduction

The world petroleum situation of the past several years has focused attention on the need for development of alternate fuels. It has been recognized for many years that vegetable oils could be burned in compression ignition engines. However, they have not been accepted as a viable substitute for diesel fuel because of inexpensive and abundant supply of petroleum-based fuels. Research efforts have been started to determine the feasibility of using vegetable oils as diesel fuel substitutes. But now it is necessary to know the performance of engines with vegetable oils as the stock of petroleum is decreasing.

Generally in transportation and agricultural sectors the Diesel Engines are used. Diesel engines meet their energy requirement from natural petroleum products. The problems associated with diesel fuels are their increasing price, atmospheric pollution and lack of sufficient availability in next few years. The purpose of this paper is to study the effects of blends of sunflower oil and diesel fuel used in a diesel test engine of current design. Specifically, this investigation covered the effect of the fuel blends on engine brake thermal efficiency, exhaust gas temperature, and brake specific fuel consumption at various blends and at various loads

Literature Review

Some literature review carried out related to the use of vegetable oils in unmodified DI diesel engines is presented here. Gopalakrishnan KV et al.. determined the fuel properties of eleven vegetable and reported that compared to diesel fuel, all of the vegetable oils were much more viscous, much more reactive to oxygen and had higher pour points. Bettis et al.. demonstrated that the variation in viscosity was due to fatty acid chain length, the number of unsaturated bonds and the interaction between the combinations.

Gupta et al.. characterized the linseed, jatropa, sunflower and rice bran oils and their esters. They reported that the methyl esters exhibited lower values of viscosity, flash point and density as compared to non-esterified oils.Juneja et al.. found that the rapeseed oil blend with diesel up to 30% could be easily used in existing engines without incorporating any modifications. Mc Donnell et al., studied the use of semi refined rape seed oil as a diesel fuel extender. The test results indicated that the rapeseed oil could serve as a fuel extender at inclusion rates up to 15-205. No signs of internal engine wear or lubrication oil contamination are reported.

Experimental Work

The viscosity of the vegetable oil is very high compared to the diesel fuel. Due to high viscosity, the oils have low volatility, poor fuel atomization and inefficient combustion. When the vegetable oil is mixed with diesel the viscosity of the blend reduces significantly. When the blend is heated the viscosity further reduces which will improve ignition qualities. Now the blend is suitable to use directly in the C.I.engines.

In the present investigation blends S 10(10% of sunflower oil + 90% diesel), S 25, S 50 are prepared. The performance of the engine is examined operating on each blend and compared with pure diesel. The blends are heated by means of engine coolant before going to the combustion chamber. The performance parameters such as brake thermal efficiency indicated thermal efficiency, brake specific fuel consumption, mechanical efficiency, exhaust gas temperature etc. are examined.

Property	**Diesel**	**Sunflower oil**
Density(gm/cc)	0.836	0.912
Viscosity(mm^2/s)	3.8	37
Calorific value(kj/kg)	45562	39575
Sp.gravity	0.841	0.924
Cetane number	55	52
Flash point(^0C)	59	220

Table 1 Properties of diesel and sunflower oil at 30^0C

Experimental Setup

Engine type	: Direct injection 4-stroke diesel engine.
Make	: Kirloskar
No. of cylinders	: One
Cooling	: water cooling
Power	: 5 HP
Rated speed	: 1500 rpm
Bore	: 80 mm
Compression ratio	: 15:1

Stroke	: 110mm
Type of loading	; Rope brake
Charging	: Naturally aspirated
Viscosity measuring instrument	: Standard redwood viscometer

The tests are conducted on a 4-stroke, single cylinder diesel engine. It consists of a fuel tank, pump, fuel filter, injector, lubricating oil filter and an air cleaner. A rope brake dynamometer is arranged to measure the torque. A 75cc burette and 3-way cock arrangement is provided for fuel measurement.

A chromel–alumel thermocouple is arranged to measure exhaust gas temperature. A Thermometer is used to measure the temperature of cooling water. Whenever the test is conducted on fuel blends, a copper tube of 12 mm diameter, made like a coil and fitted in the fuel blend tank. This copper tube coil is connected to the engine cooling system. The hot coolant flows through the tube and heats the blend before entering in to the cylinder. The temperature of the coolant noted is about 58^0C.

The engine started and allowed to run for 10 minutes at no load, to warm up and to attain rated speed. The time taken to consume 10cc of fuel is noted for every load at constant speed. Between every load application the engine is allowed to run about 10 minutes to attain the speed 1500 rpm. Firstly, the test was conducted on the pure diesel and calculated all the performance parameters, when the test conducted on the fuel blends, the engine was started with diesel and run for some time. After running for some time, the engine gases can be utilized to heat the fuel blend sufficiently. Then the fuel line is switched over for the supply of fuel blend to the engine. The time is noted to consume the oil at each load and calculated the fuel consumption, brake thermal efficiency and also measured the exhaust gas temperatures. During running of the engine, continuous supply of cooling water is provided for brake drum. The schematic diagram of the experimental setup is shown in Fig.1

The performance tests were conducted only on the fuel blends S 10, S 25, S 50, because the maximum temperature of the coolant water is only 58^0C. This amount of heat sufficient to heat the fuel blends up to S 50 only, to achieve the viscosity close to the diesel. The sunflower oil used to blend was a waste cooking oil taken from a restaurant. The oil is cleaned and filtered through a 5 micron bag filter and blended with diesel in various proportions.

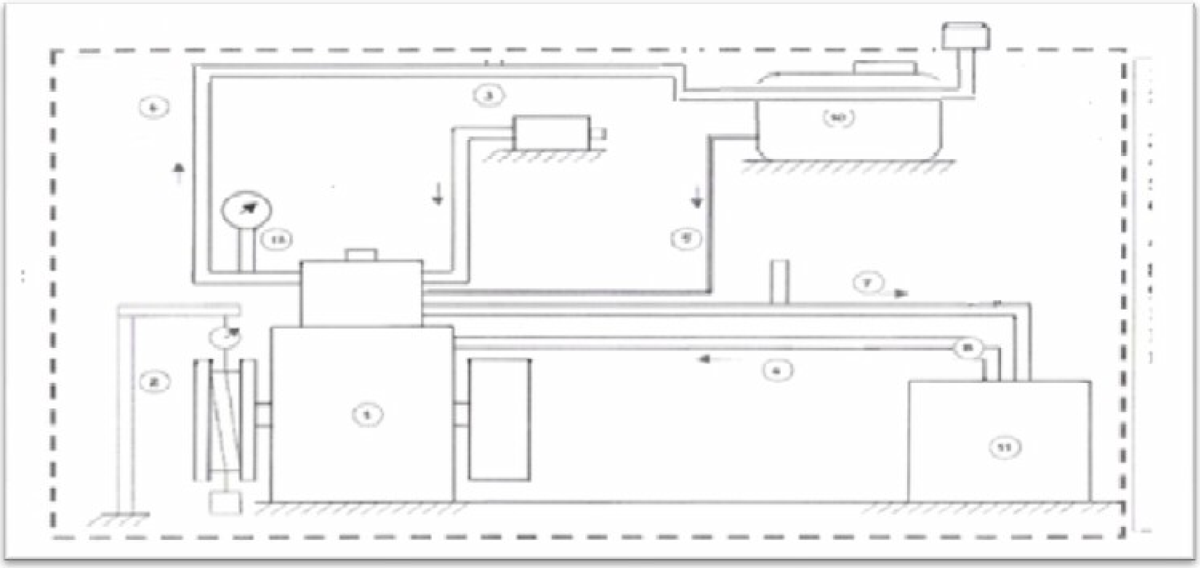

Fig. 1 The schematic diagram of the experimental setup

1. Engine
2. Rope brake dynamometer
3. Air inlet
4. Exhaust pipe
5. Fuel line
6. Pump
7. Copper tube
8. Fuel tank
9. Water tank
10. Exhaust gas temperature indicator
11. The viscosity is determined by redwood viscometer for various fuel blends as shown in Table.2

% of sunflower oil	% of diesel fuel	Density at 30^0C(gm/cc)	Viscosity (mm^2/s)
100	-	0.919	37.16
75	25	0.892	32.23
60	40	0.880	27.44
50	50	0.875	12.82
25	75	0.852	7.21
10	90	0.840	4.52

Table 2: Viscosity of various fuel blends by using redwood viscometer

It has been absorbed that the blends containing more than 25% sunflower oil have high viscosity compared to diesel

Effect of temperature on viscosity of blends

The various blends are heated and examined. The kinematic viscosities are calculated for the blends at each temperature and shown in Table-3. Relation between viscosity and temperature is shown in Fig.2. The fuel blends S10, S 25, and S 50 are achieving the viscosities almost same as pure diesel (4 mm^2/s) when they are heated to about 55^0C.

The fuel blends S 60, S 75, and S 100 are not getting viscosity values close to diesel at 55^0C. They need to be heat above 100^0C to achieve same viscosity as diesel.

As the out let cooling medium water temperature is about only 58^0C, the test is conducted on engine for S 10, S 25 and S 50 blends only. In order to test other blends of S 60, S 75 and S 100, they have to be heated more, which is possible by the heat available in the exhaust gas temperature. In the present investigation only heat available in the engine coolant water is utilized.

Temp. ^0C	S 10	S 25	S 50	S 60	S 75	S100
25	6.3	8.1	16.3	32.1	36	48.98
35	4.2	5.7	8.8	18.1	26.8	32.12
45	3.9	4.4	4.9	14.9	17.2	23.79
55	3.6	4.2	4.2	10.4	13.8	17.63
65	3.2	3.9	4.0	8.3	12.2	13.24
75	3.1	3.8	3.9	6.2	10.1	11.52

Table 3: Temperature values of various fuel blends

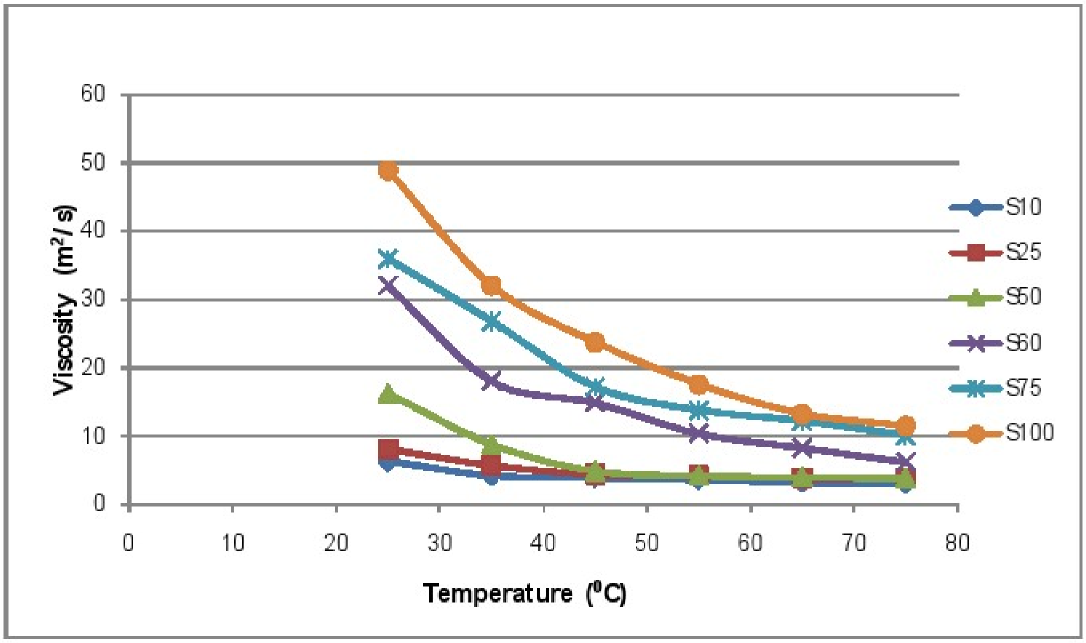

Figure 2: Relation between viscosity and temperature

Results And Discussions

The readings are taken at constant speed, N=1500 rpm for diesel and blends. The test results for various fuel blends are shown from Table 4 to Table 8.

Load (kg)	Time for 10cc (sec)	B.P kw	F.C Kg/hr	BSFC Kg/kw hr	B.th.E %	EGT °C
2	93	0.5	0.32	0.64	12.2	106
4	74	1.0	0.45	0.45	17.7	120
6	60	1.5	0.51	0.34	23.6	146
8	54	2.0	0.55	0.27	29.3	158
10	48	2.5	0.62	0.24	32.6	162
12	39	3.0	0.77	0.25	31.9	204
14	33	3.5	0.92	0.26	30.3	242

Table 4: Test Results for pure Diesel

Load (kg)	Time for 10cc (sec)	B.P kw	F.C Kg/hr	BSFC Kg/kw hr	B.th.E %	EGT ^{0}C
2	91	0.50	0.33	0.661	12.13	122
4	68	1.01	0.45	0.450	17.50	128
6	58	1.52	0.52	0.342	23.40	152
8	53	2.03	0.57	0.282	28.09	156
10	46	2.53	0.65	0.262	31.70	180
12	28	3.04	0.80	0.269	30.43	216
14	32	3.51	0.95	0.275	29.67	263

Table 5: Test results for fuel blend S 10

Load (kg)	Time for 10cc (sec)	B.P kw	F.C Kg/hr	BSFC Kg/kw hr	B.th.E %	EGT ^{0}C
2	89	0.50	0.34	0.681	12.01	132
4	65	1.0	0.48	0.480	17.19	148
6	56	1.52	0.55	0.362	22.50	160
8	50	2.03	0.61	0.302	27.19	184
10	46	2.52	0.67	0.268	30.80	202
12	36	3.04	0.85	0.280	29.22	224
14	30	3.51	1.02	0.298	28.19	292

Table 6: Test results for fuel blend S 25

Load (kg)	Time for 10cc (sec)	B.P kw	F.C Kg/hr	BSFC Kg/kw hr	B.th.E %	EGT ^{0}C
2	85	0.50	0.371	0.745	11.43	128
4	61	1.01	0.520	0.510	16.43	140
6	53	1.52	0.591	0.392	21.79	168
8	48	2.03	0.652	0.323	26.01	192
10	40	2.53	0790	0.310	27.08	212
12	33	3.04	0.962	0.320	26.78	262
14	26	3.51	1.210	0.345	24.81	334

Table 7: Test results for fuel blend S 50

Load (kg)	Time for 10cc (sec)	B.P kw	F.C Kg/hr	BSFC Kg/kw hr	B.th.E %	EGT°C
2	81	0.5	0.39	0.78	11.01	130
4	67	1.01	0.57	0.564	16.08	141
6	50	1.52	0.62	0.407	21.19	170
8	42	2.03	0.69	0.339	25.78	194
10	38	2.53	0.87	0.343	26.64	214
12	30	3.04	0.99	0.326	25.11	265
14	23	3.51	1.58	0.41	24.02	335

Table 8: Test results for fuel blend S60

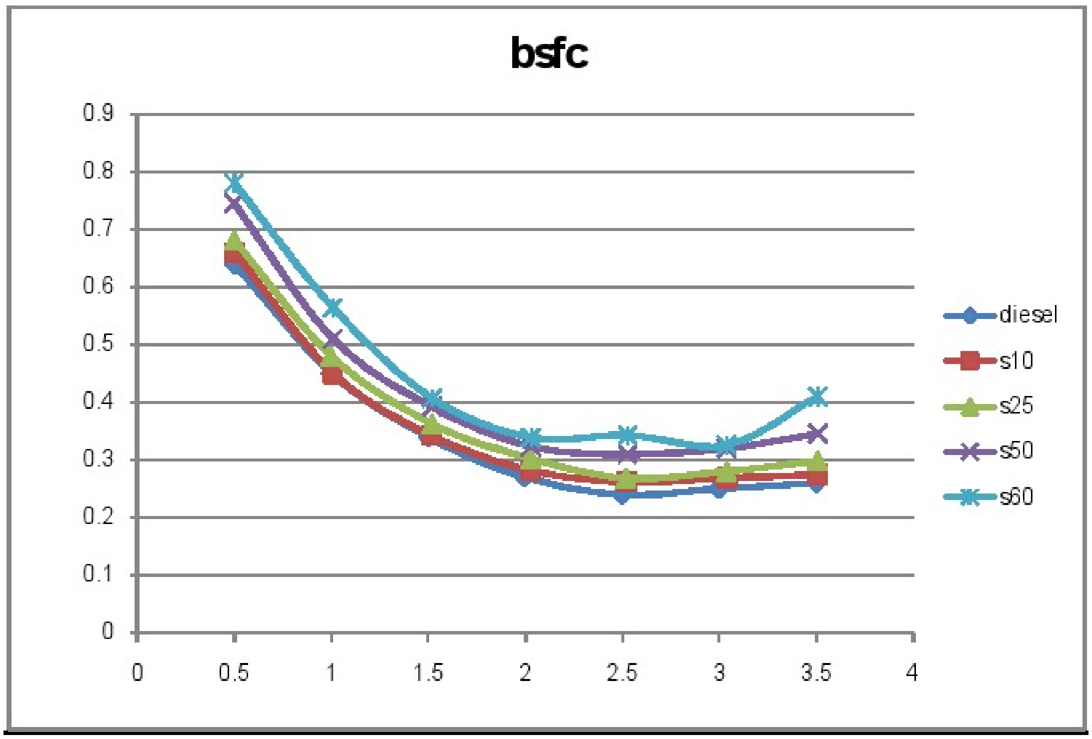

Figure 3: Effect of BP on Brake Specific Fuel Consumption (BSFC)

It is observed that the brake specific fuel consumption of the diesel as well as blends (Fig. 3) is decreased with increasing load from 0.507 to 2.53 kW of brake power. The BSFC increased with further increase in brake power. The fuel consumption is also found to increase with higher proportion of sunflower oil in the blend. Though the blends maintained a similar trend to that of diesel, the SFC in the case of blends is higher compared to diesel in the entire load range. This may be due to the combined effect of the relative fuel density, viscosity and heating values of the blends. However, the blends S 10 and S 25 have SFC values of 0.262 and 0.268 kg/kWh at 2.53 kW of brake power. The corresponding value for diesel is 0.248 at that brake power. The SFC of 0.310 is observed for the blend S 50, which is a considerable value and comparable to SFC with the diesel at the same load. The higher density of blends containing a higher percentage of sunflower oil has led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump thereby increasing the SFC. High carbon residue in the vegetable oil may cause the increase of the SFC for fuel blends.

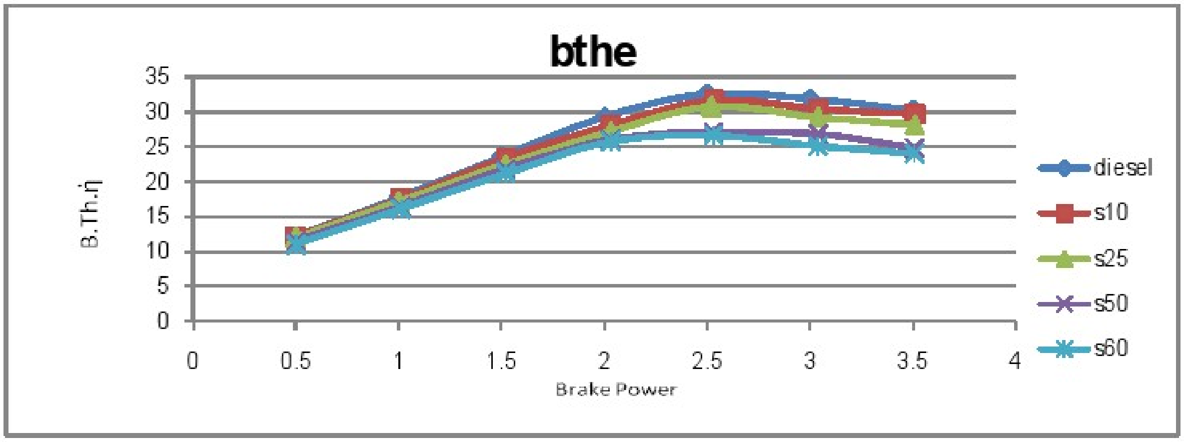

Figure 4: Effect of BP on Brake thermal efficiency (B.th.E)

The variation of brake thermal efficiency of the engine with various blends as increasing the load at constant speed is shown in Fig.4, and compared with the brake thermal efficiency obtained with the pure diesel. From the results it is observed that, initially with increasing brake power, the brake thermal efficiencies increases and attained a maximum value at a brake power of 2.53 kw. Then the thermal efficiencies decreased with further increase in brake power. The brake thermal efficiencies of the blends are lower than that of diesel throughout entire range. The maximum brake thermal efficiencies are 31.7% and 30.8% for S 10 and S 25 respectively at a brake power of 2.53 kW. For diesel, the maximum thermal efficiency obtained is 32.6% at the same brake load. The drop in thermal efficiency with increasing in proportion of vegetable oil must be attributed to the poor combustion characteristics of vegetable oils due to their high viscosity and poor volatility.

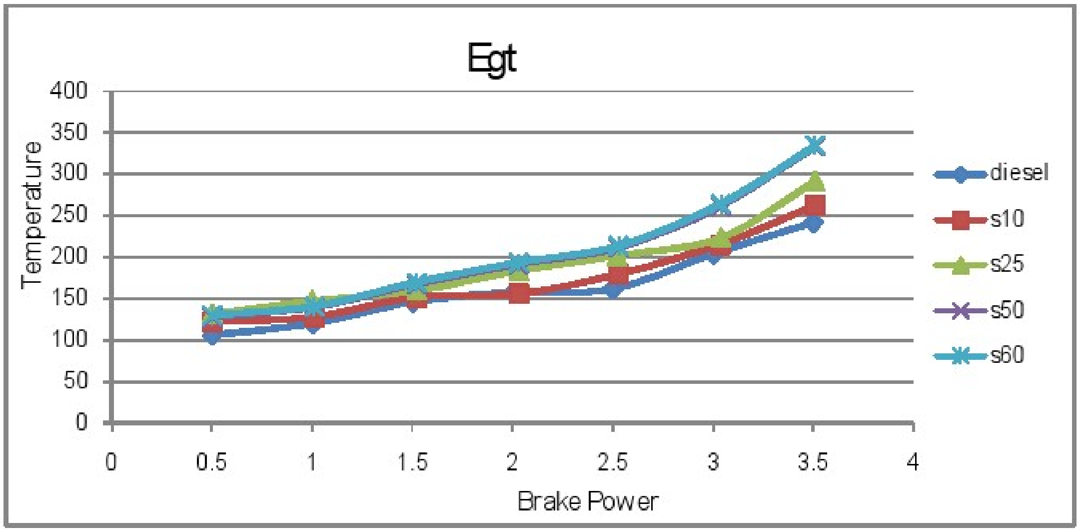

Figure 5: Effect of BP on Exhaust Gas Temperature (EGT)

Fig. 5 shows the variation of exhaust gas temperature with load and various blends. The results shows that the exhaust gas temperature increased with the increase in brake load in all the cases. The exhaust gas temperature for blend S 10 is observed close to the exhaust gas temperature of diesel The maximum exhaust gas temperature is 263^0C for S 10 blend while it is 242^0C for diesel. The maximum exhaust gas temperatures are observed as 292^0C and 334^0C for S 25 and S 50 blends respectively. The exhaust gas temperature with blends having higher percentage of sunflower oil is found to be higher at the entire load range in comparison to diesel, but deviation is observed to be greater at higher brake powers. The higher exhaust temperature with blend S 50 is indicative of lower thermal efficiencies of the engine. At lower thermal efficiency, less amount of the energy input in the fuel is converted to work, thereby increasing exhaust gas temperature.

Conclusion

In the present investigation, the high viscosity of used sunflower oil is reduced by blending it with diesel and then preheated by the engine exhaust gases, to make suitable for use in C.I.Engine. The performance of the blends are studied and compared with pure diesel.

- The blends containing used sunflower oil up to 60% (S 60) have viscosities very close to the diesel when they are heated in the temperature range of 45^0C to 55^0C. The blends above S 60 are needed to heat above 75^0C to achieve the viscosities nearer to the diesel.

- The brake thermal efficiency of the fuel blends are lower compared to diesel. It may be due to high viscosity and poor volatility of the vegetable oils. But S 10 and S 25 blends got brake thermal efficiencies very close to the diesel.
- The exhaust gas temperatures are increasing as the percentage of the vegetable oil is increasing in the blends. The S 10 and S 25 blends are showing reasonable increase in exhaust gas temperature, while it is very high for S 60.
- The BSFC of the fuel blends are higher compared to diesel. It may be due to higher fuel density and lower heating value. Fuel blends S 10 and S 25 got BSFC values close to that of diesel.
- The mixing of vegetable oils with lighter diesel fuel improves the lubricating properties of the blends.
- The fuel blends containing up to 25% sunflower oil (S 25) can be in diesel engines without any modification as their performance is same as diesel.
- As taken sunflower oil is waste cooking oil from a restaurant and fast food centre, the cost is very cheap compared to diesel.
- As vegetable oils are agricultural products, it gives a great encouragement to the agricultural sector.
- Lower emissions, environmental friendly, non-toxic, low global worming are the some other advantages of the vegetable oils.

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