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Performance Evaluation of Four - Stroke Single Cylinder DI Diesel Engine Using Different Blends of Diesel and Grape Seed Biodiesel

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ABSTRACT: ***India's rapidly expanding economy is demanding adequate energy resources for its growth. Majority of its energy consumed comes from imported fossil fuels. This has a major impact on economy as they deplete foreign currency reserves. Using them as a source of energy, challenges that are to be addressed with utmost priority are global warming and environmental pollution. Biodiesel is one such attractive, promising solution for meeting part of India's energy needs and also to reduce dependency on imports of crude oil. It also enhances energy security to energy deficit countries while reducing green house gas emissions. Biodiesel from grape seeds is of economic importance because of its value addition to by-product obtained from wine manufacturing. To overcome the drawbacks in the transesterification process, such as excess soap formation and large quantity of water wasted in retrieving biodiesel, catalytic cracking process is adopted for production of biodiesel from grape seed oil. Cracking process is carried out by selecting zeolite (ZSM-5) as catalyst among many available catalysts for obtaining biodiesel. Physicochemical properties of biodiesel obtained are tested and found to be satisfying with ASTM standards, also very close to diesel. Tests are conducted on single cylinder 4-stroke water cooled Kirloskar TV-1(DI) diesel engine to compare B25, B50, B75, B100 grape seed biodiesel with diesel in terms of engine performance, combustion and exhaust emissions. On analysis it is found that at higher load operation of engine there is minimal drop in brake thermal efficiency with grape seed biodiesel and also lower hydrocarbon emissions in comparison with diesel. Results are encouraging for further research on conversion of more plant material byproducts into biodiesel with the help of other catalysts.***

Key words: **Biodiesel, Catalytic cracking, Engine characteristics, Zeolite.**

I. INTRODUCTION

Energy from sources which are carbon neutral and easily replenished are of primary importance. Renewable energy is a well justified word for this kind of clean energy source as it can be replenished within a short period of time. They never deplete and abundant in supply, a lot can be harnessed from these energy sources for the betterment of mankind and nature.

Biodiesel is one of the sources of renewable energy and developing countries are thriving for utilisation of these energy sources to reduce their dependency on costly energy imports and to achieve significant energy security.

Vehicles running on diesel fuel play a vital role in transportation sector, major contributor in overall development, growth of civilisations and economy. On other side scrupulous usage of these diesel engines has got a irrevocable impact on environment due to emission of poisonous gases from their tail pipes. Though it is a matter of serious concern economy comes to halt without these engines. It becomes necessary to continue them and to find an alternative to diesel fuel as it is a source of pollutants. Once again biodiesel comes in and offers solution to this problem of pollution, which can be used as a fuel in diesel engines in its pure form or as a diesel additive. Biodiesel is produced from vegetable oils or animal fats which are biodegradable and non toxic. It has considerably reduced emissions, less detrimental effect on environment when compared to diesel.

Production of biodiesel gains importance due to its production from plant sources and also conversion of unviable by-products into viable products there by adding considerable economic value to them if not harnessed otherwise would have been considered as waste. One such example is wine manufacturing industry where tons of by-product grape seeds which earlier had no value, after its usage as a source of biodiesel has become subject of research. Indian wine industry is steadily growing at a healthy pace due to increasing people's awareness of fact that consumption of wine is good for health. Second thing is love for quality wine and crave to taste unique wine has become a lucrative business for many people. Due its good demand and profitability this is bringing more land into cultivation under its shade encouraging more farmers to look forward for growing grape plantations. So plentiful of available grape seed by-product can be used for extracting oil. Present work is about processing of grape seed oil into biodiesel by adopting one of the biodiesel production methods called catalytic cracking method, finding its suitability as a biodiesel fuel by comparing its physicochemical properties with that of diesel and finally testing biodiesel for its effects on diesel engine.

II. LITERATURE SURVEY

Jinlin Xue et al. [1] reported that blends of biodiesel with small content in place of petroleum diesel favours the reduction of carbon deposits, wearing of key engine parts, can help in controlling air pollution and easing pressure on scarce resources without significantly sacrificing engine

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power and economy. C.M. Fernandez et al. [2] explained techniques to extract grape seed oil from natural waste of wine industry. Transesterification of oil produced biodiesel of good quality with better oxidation stability. Conclude that ethyl esters showed good flow properties when compared to methyl esters. M. U. Kaisan et al. [3] evaluated the physical and chemical properties of biodiesel after transesterification of wild grape seeds oil for their properties such as specific gravity, viscosity, flash point, calorific value, sulfur content and confirmed that nine properties out of ten properties conform to ASTM standards except for color which is dark brown. Biodiesel obtained gave the best ASTM value for copper strip corrosion and also its suitability to be run in any diesel engine without any fear of corrosion tendencies. Nurjannah et al. [4] studied catalyst characteristics using several techniques such as Absorption Atomic Spectroscopy to analyze Si/Al ratio in catalyst samples, BET to measure surface area and pore size of catalysts, XRD to study type and structure of catalysts. They concluded synthesized HZSM-5 meet the standards of catalyst for production of biofuel from vegetable oil using catalytic cracking process. Sophi damayanti et al. [5] using gas chromatography identified, quantified linoleic acid one of the main compounds of unsaturated fatty acids in grape seed oil and also successfully transesterified grape seed oil. Agarry, S.E et al. [6] evaluated the citrus seeds (orange, grape, and tangarine) as a potential source of valuable oil due to presence of unsaturated fatty acids, studied some of its properties and concluded their suitability as a biodiesel. Le Thi Hoai Nam et al.[7] stated that MC-ZSM-5/MCM-41 as a good catalyst in the catalytic cracking reaction with higher conversion of vegetable oil sludge into biofuel. M.M.Yunus et al. [8] extracted oil from African grape seed and tested its properties, compared them with recommended standards of biodiesel for its suitability as a fuel for running diesel engines. They suggested the potential of wild grape seeds oil as a good source of biodiesel, which could be exploited as an alternative source of fuel.

III. CATALYTIC CRACKING PROCESS

Complex hydrocarbons can be easily broken into less complex structures with this catalytic cracking process. In this process reaction takes place at lower temperatures and pressures by the addition of catalyst. Quantity and quality wise superior oil with very close properties to that of diesel is obtained. In catalytic cracking process, sufficient oil and catalyst mixture is filled into a batch reactor in the proportions of 50gms of zeolite catalyst per one litre of grape seed oil. When heated a rapid chemical reaction process takes place, in the process complex structures are broken down in the reactor to a simple structure producing low density and low viscosity biodiesel. Yielding of biodiesel starts at a temperature of 140^{0}C and continues up to 275°C with some ten percent residue remaining in the reactor.\

Catalytic cracking biodiesel plant shown as schematic diagram of experimental set up in Fig.1 consists of a batch reactor with oil inlet to pour grape seed oil mixed with zeolite catalyst, pressure gauge to indicate pressure in the reactor, drain hole to remove residue and safety valve to safe guard reactor.

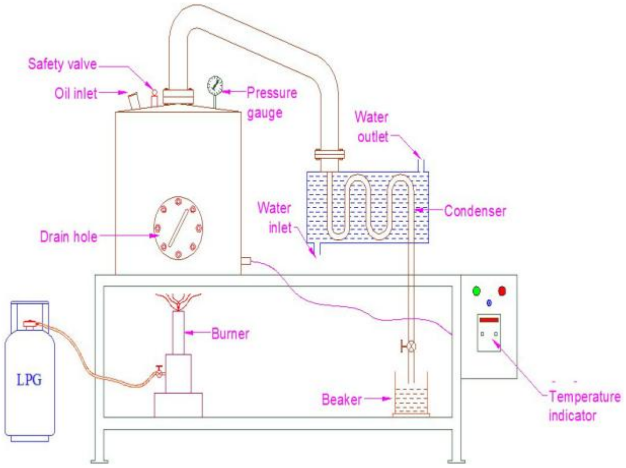

Fig .1: Schematic Diagram of the Experimental Set Up

Gas burner at the bottom of the batch reactor supplies heat. Temperature indicator is fitted to display inside temperature of the reactor. Produced smoke in the reactor passes through piping to condenser and finally smoke is condensed into liquid thus obtained is called biodiesel which is collected into the calibrated beaker.

IV. FUEL PROPERTIES

Table .I: Fuel blend percentages

Notation	Fuel Quantity (litres)	Biodiesel Quantity (ml)	Diesel Quantity (ml)
B25	1	250	750
B50	1	500	500
B75	1	750	250
B100	1	1000	-

Fuel properties of diesel and different blends of catalytically cracked grape seed biodiesel with diesel are tabulated in Table .II

Table II: Comparison of Properties of Test Fuels

Properties	Diesel	Grape seed biodiesel (Zeolite as catalyst in Catalytic Cracking process)			
		B25	B50	B75	B100
Kinematic viscosity @40^{0}C (x 10^{-6} m^2/s)	2.56	2.45	4.70	6.95	9.20
Gross calorific value (kJ/kg^{0}C)	44631	42941	41654	40367	39080
Sp.gravity @15/15 ^{0}C	0.835	0.8437	0.8590	0.8743	0.8896
Flash point (PMCC method)^{0}C	44	49	52	55	58
Fire point (PMCC method)^{0}C	48	75	80	85	90
Pour point ^{0}C	-14	-10	-10	-10	-10
Density @ 15^{0}C (kg/m^3)	834	843	858	874	889

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V. EXPERIMENTAL SET UP

Investigation work is carried out on a naturally aspirated Kirloskar TV-1, 5.2 kW. diesel engine with specifications tabulated in Table III and schematic diagram with clear indication of several key components of test rig set up are shown in Fig. 2

Table III: Specifications of Kirloskar TV-1 Engine

TYPE	**Water Cooled, Single Cylinder, Four Stroke Diesel Engine**
Loading Device	Eddy current dynamometer
Dynamometer Arm Length	0.195m
Stroke length	0.11m
Compression ratio	17.5:1
Bore diameter	0.0875m
Speed	1500 rpm
Power	5.2kW(7hp)
Orifice Diameter	.02m
Mode of Starting	Manually Cranking
Injection Pressure	215.7 bar
Injection Timing	23^0C before TDC

Engine is fitted with eddy current dynamometer for load variation and precise readings. Fuel combustion characteristics of the engine are recorded using 619 Indi meter hardware preloaded with Indwin - software version2.2. Time is noted using stop watch for 10cc fuel consumption of the engine indicated by equivalent fuel drop in glass burette. Digital tachometer is used to measure the speed of the engine. Using AVL gas analyzer exhaust gas emissions CO, HC, NOx are measured. Density of smoke is recorded with AVL smoke meter. It's important to check for prevailing ambient conditions such as atmospheric pressure and temperature before conducting tests on the diesel engine. These conditions have their own impact on fuel-air mixing ratios as well combustion process. So it is necessary to conduct the tests on engine at constant ambient atmospheric conditions.

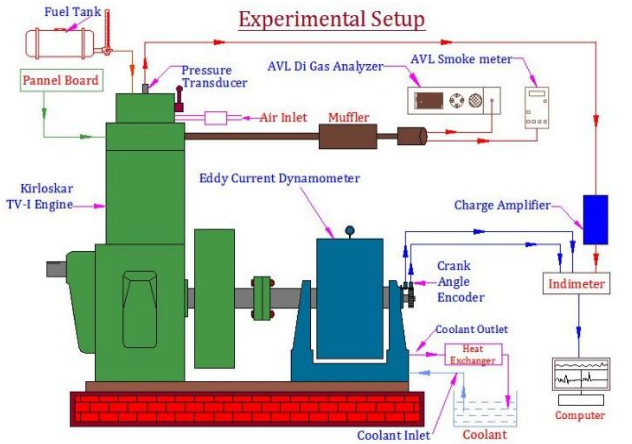

Fig. 2: Schematic Diagram of Test Rig Set Up

VI. RESULTS AND DISCUSSION

A. Performance Characteristics

From Fig. 3, it is evident that *Brake Thermal Efficiency (BTE)* in general of grape seed biodiesel blended with diesel and diesel is very close in nature. The maximum brake thermal efficiency is 27.2% for diesel and very next close value recorded is for B25 that is 26.9%. Remaining B50, B75 and B100 maximum brake thermal efficiencies are 26.2%, 26.3%, and 25.8% at full load. Percentage of grape seed biodiesel in diesel increases, there is reduction in brake thermal efficiency compared to engine run by diesel fuel. This can be attributed to low calorific value of grape seed biodiesel.

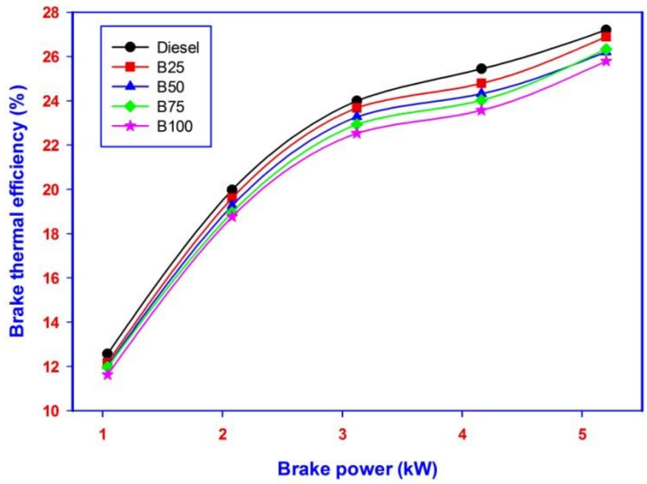

Fig. 3: Brake Thermal Efficiency versus Brake power.

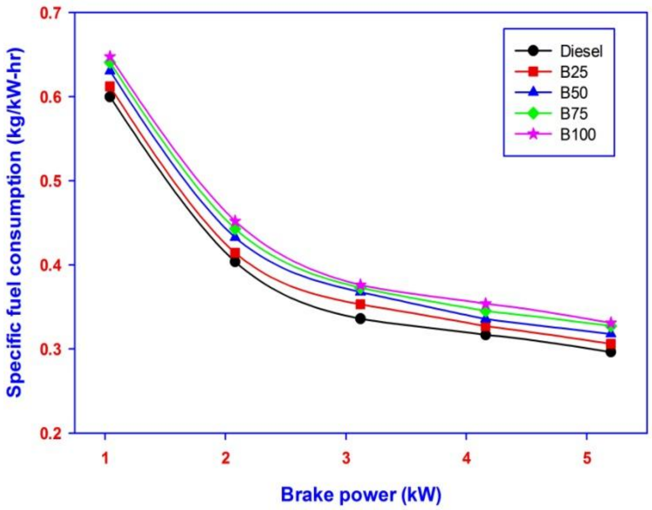

Fig. 4: Specific fuel consumption versus Brake power

Fig. 4 is comparative analysis of *Specific Fuel Consumption (SFC)* of test fuels against varying load conditions. Specific fuel consumption of the engine is decreasing for all test fuels on increasing loads. The fuel consumption is increasing with grape seed biodiesel blends from B25 to B100 when compared to diesel to develop same power output. This is because of lower calorific value of blends which leads to injection of more fuel to maintain power output in comparison with diesel. B25 is giving similar specific fuel consumption when compared with diesel and with increase in load it is very close to diesel. Engine on full load it is observed specific fuel consumption is more with B-100 fuel in comparison with diesel. Reason is higher density of vegetable oils leads to more fuel discharge with respect to diesel fuel.

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B. Combustion Characteristics

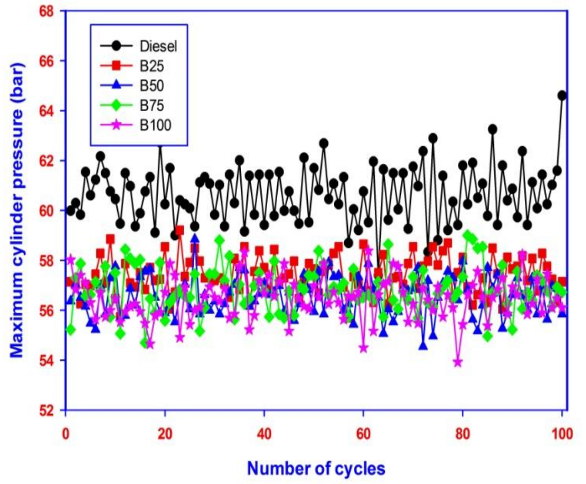

Fig 5: Maximum cylinder pressure versus Number of cycles

Fig 5 is about maximum in cylinder pressures attained in diesel engine for 100 cycles of operation with all test fuels. Maximum in cylinder pressures are observed in case of diesel fuel because of better atomization and complete combustion process. B25 fuel in cylinder pressures are lesser by 3 bar approximately to that of diesel fuel. Clearly it is noticed that in cylinder pressures are decreasing with increase in blend percentage of biodiesel due to increase in viscosity of fuel resulting in poorer atomization. B100 is giving least in cylinder pressures of all tested fuels.

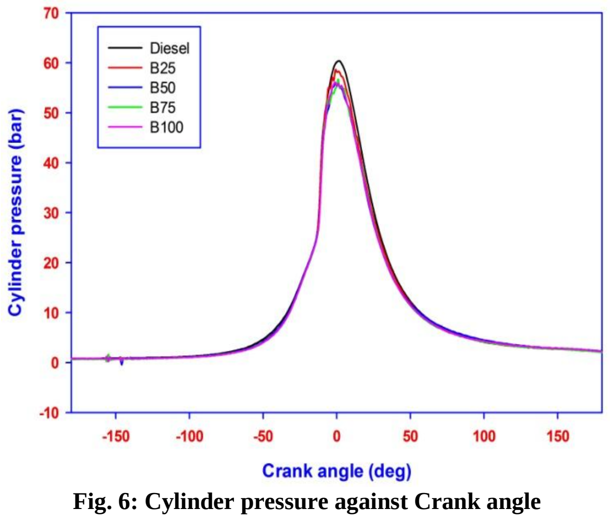

Fig. 6: Cylinder pressure against Crank angle

Fig. 6 shows the rise in cylinder pressure for different fuels at rated load with respect to crank angle. Curves closeness tells that cylinder pressure rise for all test fuels is similitude in nature. Pressure rise is maximum for diesel compared to other test fuels. B25 gives very close or equal pressure rise with a maximum difference of approximately 2% due to similar atomization. Increase in percentage of grape seed biodiesel in diesel reduces the cylinder pressure. This can be due to more density of vegetable oils compared to fossil fuel derived diesel. It is clear from the above graph cylinder pressure is least for B100 but it is less by 4% only.

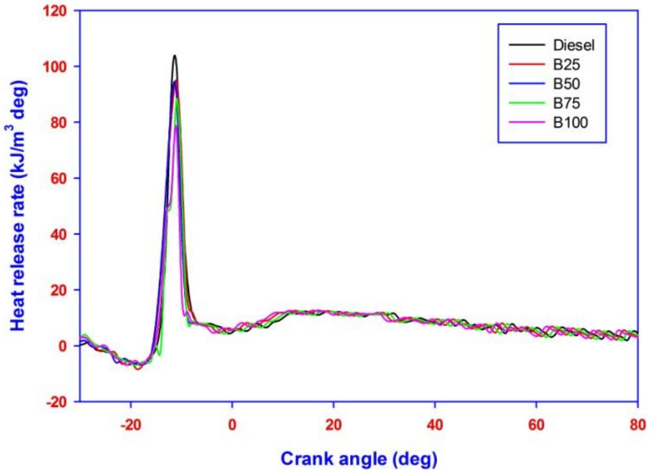

Fig. 7: Heat Release Rate against Crank angle

The above Fig.7 is about heat release rate pattern per degree of crank angle for the fuels at full load. The diesel curve is followed by that of B25, B50, B75 and B100 at full load. Diesel accumulation is more in the delay period, which releases the maximum heat as it is having higher calorific value. Heat release rates for B25, B50, B75 and B100 are lower due to shorter ignition delays and higher viscosities compared to diesel at full load. Heat release rate of B100, B75, B50 and B25 is approximately 20%, 13%, 7%, and 6% less than diesel. B25 gives the maximum heat release rate and B100 gives the least compared to other blends.

C. Emissions

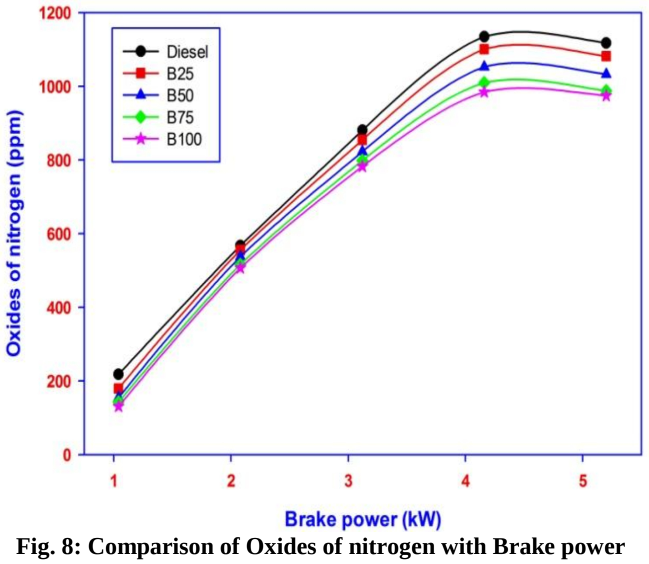

Fig. 8: Comparison of Oxides of nitrogen with Brake power

From the Fig. 8 it is observed that formation of oxides of nitrogen are increasing for all test fuels up to 80% load and slightly decreasing at full load. Diesel is emitting more NO_x for all loads the reason may be higher heat release due to higher calorific value compared to blends of the grape seed biodiesel. Considerable reduction in NO_x emission is noticed with increase in biodiesel blend in fuel. B100 recorded least NO_x emissions among all tested fuels.

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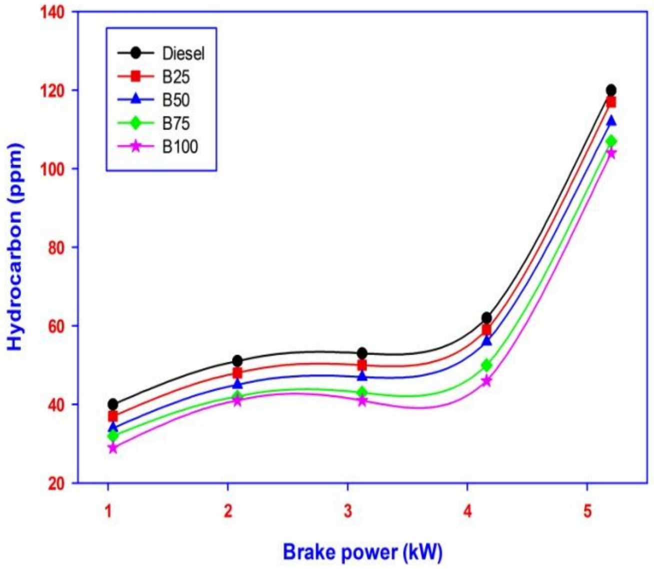

Fig. 9: Release of Hydrocarbon with increase in Brake power

It is inferred from Fig 9 that hydrocarbon (HC) emissions are increased with increase in load or brake power however, hydrocarbon emission for diesel is more compared to all other test fuels. With increasing percentage of grape seed biodiesel in diesel there is decrement in hydrocarbons emissions because of less wall quenching and bulk quenching. Among all test fuels B100 is having least hydrocarbon emissions.

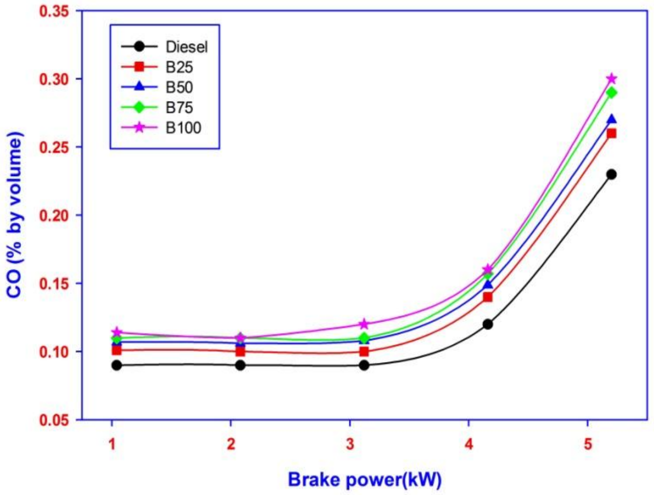

Fig. 10: Release of CO with increase in Brake power

Fig. 10 reveals that carbon monoxide emissions are increasing from B25 to B100 when compared to diesel. It is noticed that CO emissions are increasing with increasing load on the engine for all test fuels. In the catalytic cracking process oxygen in biodiesel escapes out to atmosphere or it might be consumed in the reaction process for better oil yield depriving the complete oxidation of carbon atom. Carbon monoxide emissions are very high for B100 when the engine is running at peak load.

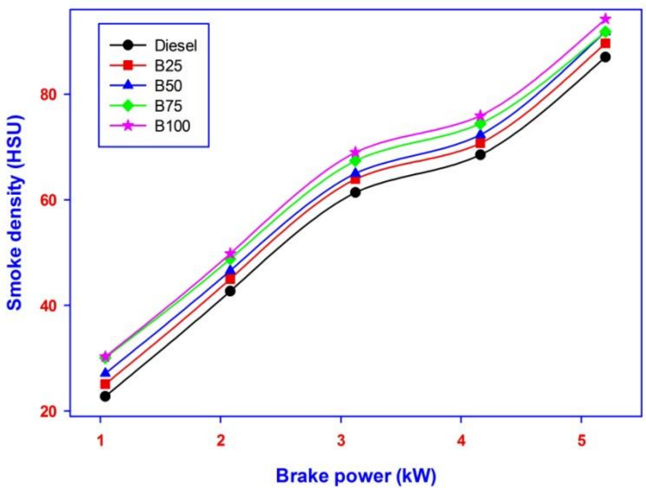

Fig. 11: Smoke density versus Brake power

Figure 11 gives clear indication of increase in smoke density from B25 to B100 compared to diesel. At maximum load the smoke opacity is 87, 89.6, 91.8, 91.8 and 94.2 HSU for diesel, B25, B50, B75, and B100 respectively. This may be due to heavier molecular structure, vegetable oil double bonded chemical structure, and higher viscosity of grape seed biodiesel and their blends. The number of double bonds present in the fatty acid is strongly related to emissions. These factors may be responsible for incomplete and slow combustion resulting in higher smoke emissions.

VII. CONCLUSION

Grape seed oil extracted from grape seeds is treated by catalytic cracking process using zeolite(ZSM-5) as catalyst with constant supply of heat to obtain biodiesel that is suitable to be used as fuel in CI engines. Grape seed biodiesel and diesel fuel blends are tested on the four stroke single cylinder diesel engine. Test results are plotted and on analysis it is inferred that performance characteristics such as brake thermal efficiency for B25 is similar to diesel. Specific fuel consumption curves of diesel and B25 are in adjacency when compared to all other test fuels. Combustion characteristic feature heat release rate of diesel fuel is higher by only 6% in comparison with B25. Emissions such as NO_x and HC are reduced considerably whereas CO and Smoke density are increasing with the blend percentage of grape seed biodiesel in diesel compared to diesel. B100 recorded a high value of smoke density of 94.2 HSU of all test fuels. It can be concluded that grape seed biodiesel is a possible substitute to diesel fuel. There is a future scope for conversion of more unviable plant material by-products into biodiesel with the help of other catalysts to get best properties and yield of biodiesel. Finally testing obtained biodiesel fuel for its effect on engine performance.

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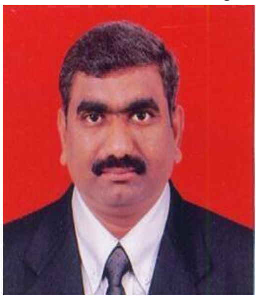

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