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PUMPKIN SEED OIL BIODIESEL AN ALTERNATE FUEL TO DIESEL: A REVIEW

SHAIKH ABDUL AHTESHAM[1], OMPRAKASH HEBBAL[2]

[1]M. Tech student, Department of Mechanical Engineering, PDACE, Kalaburagi
[2]Prof. Department of Mechanical Engineering, PDACE, Kalaburagi

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Abstract - The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present scenario. Vegetable oil's physical and chemical properties are close enough to mineral diesel and may be used as alternative to diesel, but long-term use of vegetable oils or their blends possess various operational and durability problems in the engine, and need to be modified (biodiesel). Transesterification is found to be an effective technique for the vegetable oil formulation as a fuel. The present work deals with review of literature on verifying the suitability of pumpkin seed oil and its biodiesel as an alternative to the diesel. From literature review it is found that brake thermal efficiency of pumpkin seed oil –diesel blends are lower than that of diesel and having higher emissions. Performance of 20% of pumpkin seed oil biodiesel blend with diesel is in line with that of pure diesel. Smoke and NOx emission of pumpkin seed oil methyl ester are higher and CO and HC emission are lower than that of diesel. Increase in injection pressure up to 210 bar improves the performance. Addition of n-butanol with pumpkin seed oil enhances its performance.

Key Words: - pumpkin seed oil, pumpkin seed oil methyl ester, transesterification

1. INTRODUCTION

Diesel engine is a most versatile and robust in construction, being so largely these engines are used in industries, transportation, agriculture sector etc. Since its invention diesel fuel is explored continuously from the earth crust. The diesel fuel is limited in reserves and lack to last for next 35-45 years [1]. On other hand diesel engines emits greenhouse gasses, which are determinate to flora and fauna. Apart from this the diesel reserves are available in limited part of the world (Mideast), so has political disturbances which effects their continuous supply. All these necessitated to find an alternative fuel to the diesel. Many researches worked on alternative fuel such as alcohols [2], vegetable oils and their derivatives [3], liquid petroleum gas [4-5], hydrogen etc. Among these esters of vegetables oil called biodiesel. The biodiesels of Peanut oil, Jatropha oil [6], Pongamia oil [7], Mahua oil [8], Neem oil [9], deccan hemp [10] etc. were successfully tested on diesel engine. The advantages of biodiesel are minimum sulphur and aromatic content and higher flash point, lubricity and Cetane number their disadvantages include higher viscosity, lower calorific value and volatility. Performance of diesel engine with 20 % addition of biodiesel that is (B20) is a most acceptable worldwide. Emission of HC and CO with (B20) are reduced NO_x emission are higher than that of diesel [11].

In this project an attempt is being made to review on pumpkin seed oil and its biodiesel, their characteristics, and use in diesel engine as an alternate fuel. Further effect of different additives on the performance, emission and combustion characteristics are reviewed.

2. Physiology of pumpkin seed and plant

Pumpkin plant of the cucurbitaceae family generally grow in the tropical, subtropical, arid and temperate climates of the world. The scientific name of pumpkin is *cucurbitaceae argysperma*. In West Africa, pumpkins are planted in the months of April to June. Pumpkins have been cultivated for various reasons ranging from nutritional to medicinal purposes. Pumpkin seed oil has been extracted in Australia, Slovenia, and in Hungary with variations in the range of the oil content [12]. A rich vegetable oil obtained from the seeds of the pumpkin (Cucurbita maxima) by crushing such produced oil is called as pumpkinseed oil. Pumpkinseed oil has two colors at the same time green and red. The red color comes from carotene and the green color came from chlorophyll. Refined pumpkinseed oil has a straw yellow color [12]. Pumpkinseed oil methyl ester (PSOME) was produced by means of transesterification process using pumpkinseed oil. The oil content of the pumpkin seed varies from 42–54% and the composition of free fatty acids (FFA) is dependent on several factors (variety, area in which the plants are grown, climate, state of ripeness). The dominant FFA comprise palmitic acid (C16:0, 9.5– 14.5%), stearic acid (C18:0, 3.1–7.4%), oleic acid (C18:1, 21.0–46.9%) and linoleic acid (C18:2, 35.6– 60.8%) [13]. Potential of pumpkin seed is the order of 64 thousand tonnes in India. State of Orissa is the highest producer of these seeds [14].

Moreover, pumpkin seed is a rich source for medical applications and includes various bioactive compounds such as ω–3, ω–6 and ω–9 fatty acids, α–tocopherols and γ–tocopherols, Δ5– sterols and Δ7–sterols, β–carotene and lutein. [13]

Figure 1(a) and 1(b) shows the pumpkin fruit and pumpkin seed.

Fig.1(a). Pumpkin fruit Fig.1(b). Pumpkin seeds

3. Properties of pumpkin seed oil and its methyl ester

The pumpkin seed oil contains various fatty acid. Various properties of pumpkin seed oil are density, viscosity, flash point, fire point, cloud point, cetane number, calorific value etc. Different types of fatty acids which are present in pumpkin seed oil are described in Table 1. Further Table 2 shows physical and chemical properties of pumpkin seed oil and its methyl ester.

Table: 1 Fatty acid composition in pumpkinseed oil [14]

Composition of pumpkinseed oil	**Fatty acid (%)**
Palmitic (16:0)	12.51
Stearic (18:0)	5.43
Oleic (18:1)	37.07
linolic (18:2)	43.72
linolenic (18:3)	0.18
Lignoceric (24:0)	0.06
SUMMARY	
Saturates	27
Monounsaturated	18
Polyunsaturated	55

Table: 2 Physical and chemical properties of pumpkin seed oil and its methyl ester

properties	Diesel	P.Chandrashekar et al. [15]		Elanthirayian.A et al. [16]	M.kannan et al. [17]	Alexander.pr et al. [18]
		PSO	POME	PSO	POME	POME
Kinematic viscosity (40⁰C)	3-5	35.6	4.41	35.6	5.67	4.335
Density kg/m³	860	921.6	883.7	921.6	842	878
Flash point(⁰C)	45-76	>230	>120	>230	128	125
Sulphur content in %	0.05	2	2	-	-	-
Water content ppm	-	584	490	584	-	-
Calorific value Mj/kg	44.8	35.1	34.27	35.1	36.2	34.50
Cetane number	40-55	52.6	59.8	52.6	-	-

Kinematic viscosity: The viscosity will arise due to internal molecular friction within a fluid producing the frictional drag effect. There are two related measures of fluid viscosity namely dynamic and kinematic viscosity. It is determined by redwood viscometer instrument. The fuel should have a viscosity low enough so that it can easily flow through the fuel system and the strainer at the lowest working temperatures. From the Table 2 it is observed that kinematic viscosity of pumpkin seed oil is 35.6 mm²/sec. Further it is observed that kinematic viscosity of pumpkin oil methyl ester ranges from 4.33 to 5.67 mm²/sec, which is well comparable with that of diesel. Atomization of pumpkin oil methyl ester is much better than that of pumpkin seed oil. In the process of transesterification pumpkin seed oil viscosity reduces from 35.62 to the order of 5 units

Density: A material's density is defined as its mass per unit volume. It is, essentially, a measurement of how tightly matter is crammed together. The hydrometer is used to determine the density. The density of pumpkin seed oil is 921.6 kg/m³. The density of pumpkin oil methyl ester ranges from 842 to 883.7 kg/m³, which is close to the density of diesel. The density of pumpkin oil methyl ester is much better than that of pumpkin seed oil. In the process of transesterification density of pumpkin seed oil reduces from 921.6 to the order of 842 kg/m³.

Flash point: Flash point is defined as the lowest temperature of a liquid at which its vapours will form a combustible mixture with air. It is a convenient and reliable classification of the flammability of many substances. It is observed that the flash point of the pumpkin seed oil is 230⁰C. In the process of transesterification, the flash point of pumpkin oil is reducing from 230 to 120⁰C. The flash point of pumpkin seed oil and its methyl ester are much higher than that of diesel. Hence it is safe to store and transport.

Sulphur content: The sulphur content of the pumpkin seed oil and its methyl ester is 2 %. This is not a desirable property.

Water content: It is observed that the water content in the pumpkin seed oil and its methyl ester are 584 ppm and 490 ppm respectively.

Calorific value: The amount of energy produced by the complete combustion of a unit mass of `fuel. The calorific pumpkin seed oil 35.1 Mj/kg. Further it was observed that the calorific value of pumpkin oil methyl ester is ranges from 34.27 to 36.2 Mj/kg, which is near to diesel. In the process of transesterification, the calorific value of pumpkin seed is reducing from 35.1 to 34.20 Mj/kg.

Cetane number: It is observed that the cetane number of pumpkin seed oil and its methyl ester are 52.6 and 59.8. Which is well comparable with diesel.

4. Performance, emission and combustion characteristics

4.1 Pumpkin seed oil

Alexander et.al [18] conducted experiments for variable loads like 0.2, 1.37, 2.67, 3.88, and 5.09 kW at rated speed, with injection pressure of 210 bar and cooling water exit temperature at 65°C. Three blends of all types of vegetable oils such as 10%, 20% and 30% are used in this experimentation. The vegetable oils and their blends with diesel are heated externally to a required temperature as stated earlier before injecting into the test cylinder. The engine was sufficiently warmed up and stabilized before taking all the readings. The performance and emission parameters of oils are compared to those of pure diesel. The specifications of engine used by Alexander is a single cylinder 4 stroke, 5.09 kW diesel engine, at rated speed of 1800.

4.1.1 Performance characteristics

Brake thermal efficiency

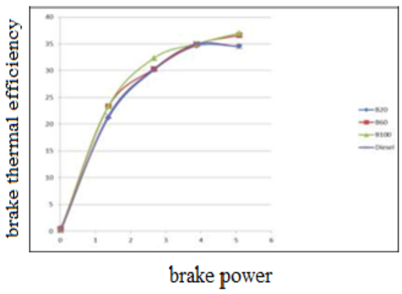

Fig 2 Variation of Brake thermal efficiency with brake power[18]

Alexander et.al. [18] observed as shown in Fig 2 that the variation of brake Thermal Efficiency with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. Brake thermal Efficiency blends of pumpkin seed oil is comparatively higher to that of Diesel. B60 and B100 are showing higher values i.e. 36%, but results regarding B20 is closer enough to diesel.

4.1.2 Emission characteristics

NO_x emission

Fig 3 the variation of Nitrogen Oxide emission with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. When applying load, B20 is higher than diesel and B100 averagely emits low NOx than the other blends, but differ at peak load.

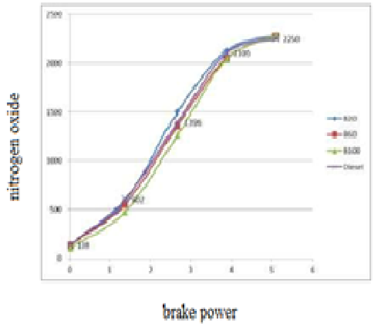

Fig 3 Variation of NO_X emission with brake power [18]

CO emission

Fig 4 shows the variation of carbon monoxide emissions with brake power output for pumpkin seed oil and its blends with Diesel in the test engine. CO emission for blends of pumpkin seed oil is compared with diesel at all loads. At low loads B100 is high and B60, B20 is lower than the diesel. After 50% of load B100 start decrease, at peak load B20 is high emission

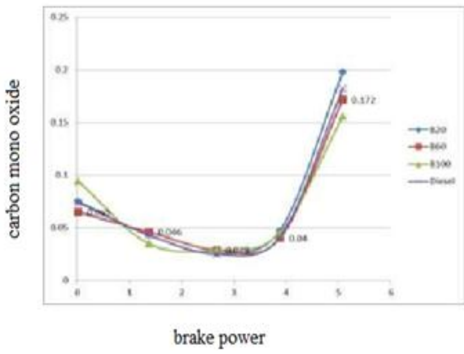

Fig 4 Variation of CO emission with brake power [18]

HC emission

Fig 5 shows the variation of hydro carbon emission with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. At low load B100 is higher and B20 is lower, after peak load B100 is lower emission. Diesel is higher emission than the other blend.

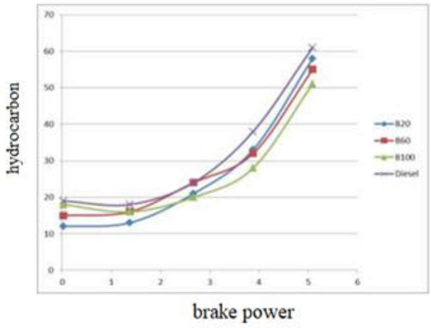

Fig 5 Variation of HC emission with brake power [18]

4.2 Pumpkin seed oil methyl ester/biodiesel

Kannan at el. [17] used a single cylinder four-stroke, direct injected, air cooled 4.5 kW diesel engine at rated speed of 1500 rpm. Engine is loaded with eddy current dynamometer, and completed to calculate the load from 0 to 100% with 25% of increments the engine is warmed up for 30 minutes for a continuous run using pure diesel fuel at a constant speed of 1000rpm a conducting test is required for each load and the readings were recorded. A fuel consumption time was noted with the help of a stopwatch for 10cc fuel which is filled in the burette. Emission of pumpkin biodiesel and its several blends and some emission gases were found by AVL smoke meter.

4.2.1 Performance characteristics

Brake thermal efficiency

Kannan et.al [17] in their experiment determined brake thermal efficiency of pumpkin seed oil biodiesel and its blends (B0, B20, B40, B60 and B100) as shown in the Fig 6. When the engine is at maximum load the blend B100 results in lowest BTE due to high viscosity and low calorific value. The blend B20 has high brake thermal efficiency of 33.4%, which is near to the efficiency of diesel i.e.; 36.1%.

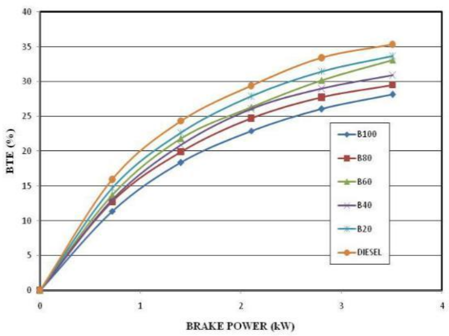

Fig 6 Variation of brake thermal efficiency with brake power[17]

Brake specific fuel consumption

Kannan et.al. [17] observed that BSFC slightly increases during 100% loading conditions as shown in Fig 7. Due to low calorific value, B100 results in maximum BSFC. The minimum brake specific fuel consumption of B20 and diesel are well comparable i.e.; 0,26 kg/kW-h.

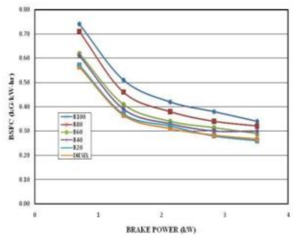

Fig 7 Variation of Brake specific fuel consumption with brake power

4.2.2 Emission characteristics

NO_X emission

According to M. Kannan at el. [17] NO_X emission increases with the increase in brake power this attribute to higher heat release at full load as shown in Fig 8. NO_X emission at B100 is 17% higher than the diesel at full load. The NO_X emission decreases with decrease in quantity of biodiesel in blends. Lowest NO_x emits at B20 and which is very close to that of diesel.

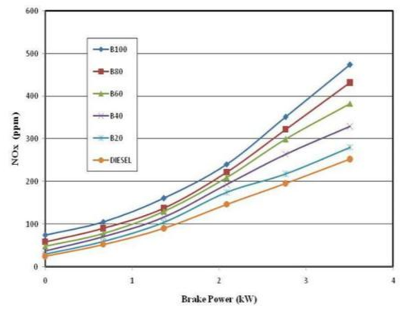

Fig. 8 Variation of NOX emission with brake power

CO Emission

Kannan at el. [17] indicated that, due to the lack of air and low flame temperature, CO and CO_2 are formed. In combustion chamber, there is an increment in CO-radiant along with the load, as the load increases the CO emission also increases as shown in Fig 9.

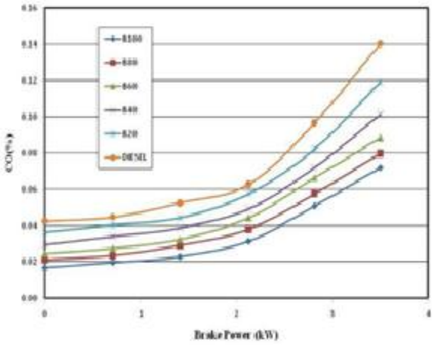

Fig 9 Variation of CO emission with brake power

Hydrocarbon emission

Kannan at el. [17] observed that, the hydrocarbon emission of various blends B0, B20, B40, B60, B80, B100at 100% load are 41,32,25,24,16,26 and 18 ppm respectively (Fig 10). When compared to diesel fuel in the HC emission, B40 is lesser and the blends like B60, B80 and B100 have higher emission. In complete combustion is the source of hydrocarbon emission. When the cylinder temperature increases the HC, emissions decreases at high loads due to reduction in quenching effect.

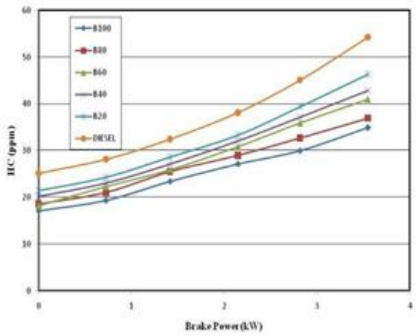

Fig 10 Variation of HC emission with brake power

Smoke opacity

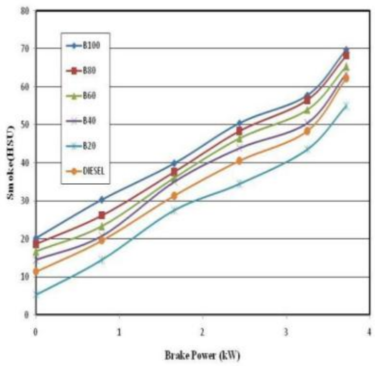

Fig 11 Variation of smoke opacity with brake power

The characteristics if smoke opacity and brake power was shows in Fig11. The highest value for various blend ratios is B0, B20, B40, B60, B80, B100 are 59,75,60,50,39.62 and 52.5 %. Diesel fuel is 51% less when compared to the smoke emission of B100 emission is reduced by 6.4% due to the addition of catalyst to B40 which is agreeing with previous studies. The radiant of B40 is than the diesel by 12.3% due to its higher oxygen content and efficient burning.

Exhaust gas temperature

The variation of exhaust gas temperature with brake power for various blends of pumpkin seed oil biodiesel and diesel is Fig. 12. Kannan at el. [17] observed that biodiesel blend causes poor atomization of fuel due to a high viscosity which leads to the presence of unburnt fuel with small traces in the premixed ignition phase. The EGT values for various blend ratios at 100% load are 428, 464, 447, 470, 418, 438 and 442 ^{o}C respectively.

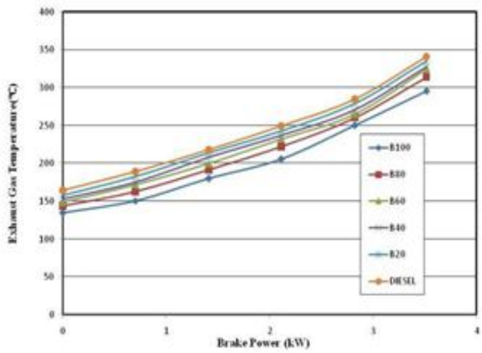

Fig. 12 Variation of exhaust gas temperature with brake power [17]

4.3 Combustion characteristics

Chandrasekar et.al [15] performed experimental test at different loads condition in a single cylinder, four stroke and air-cooled direct injection diesel engine developing power of 4.4 kW at rated speed of 1500 rpm. In their experiment the combustion characteristics of a diesel engine fueled with methyl ester of pumpkin oil (PSOME) and its diesel blends (10%, 20%, 30%, 40% and 50% by volume basis) were evaluated and compared with that of diesel fuel.

Pressure crank angle diagram:

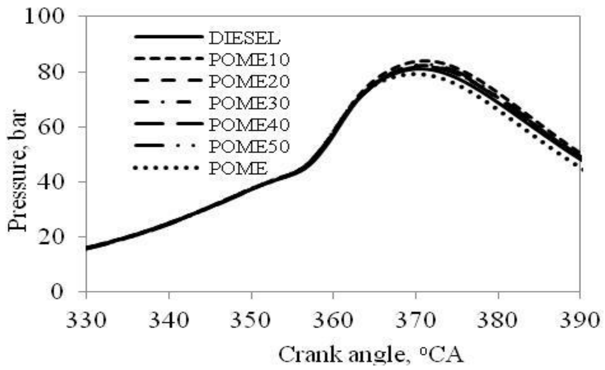

Fig. 13 Variation of cylinder pressure with crank angle [15]

Chandrasekaar et.al [15] indicates that in a compression ignition engine, the peak cylinder pressure depends on the burned fuel fraction during the premixed burning phase, *i.e.* the initial stage of combustion. The cylinder pressure is characterized by the ability of the fuel to mix well with air and burn. The pressure variation with crank angle is shown in Fig 13, for diesel, PSOME and its diesel blends. It is observed that the peak pressure of biodiesel blends is higher than that of diesel fuel followed by 10%, 20%, 30%, 40% and 50%. This may be due to the ignition delay period that increases with the decrease of engine load. The diesel fuel has longer ignition delay period so, the combustion starts later for diesel fuel than biodiesel blends. For PSOME, the cylinder pressure is lower than diesel, due to higher viscosity and lower volatility of biodiesel.

Heat release rate:

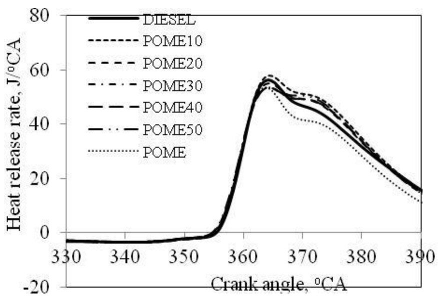

Fig. 14 Variation heat release rate with crank angle [15]

The comparison of heat release rate of PSOME and its diesel blends with diesel is shown in Fig 14. Due to heat loss from the cylinder and the cooling effect of the fuel vaporizing as it is injected into the cylinder, the heat release rate is slightly negative during the ignition delay period. It can be observed that the heat release rate of 10% blend is higher than that of diesel but other diesel blends (20%, 30%, 40% and 50%) and PSOME is lower than that of diesel, which may be attributed to the lower calorific value of the blends and POME than that of diesel fuel. A higher rate of heat release occurs at PSOME10 diesel blend may be the reason of higher boiling point. At the time of ignition, less fuel/air mixture is prepared for combustion with the diesel blends; therefore, more burning occurs in the diffusionbur ning phase rather than in the premixed phase. It is observed that the maximum heat release rate of 56.41 J/ °CA is recorded for diesel at 4°aTDC, while POME records its maximum heat release rate of 53.705 J/°CA.

Combustion duration

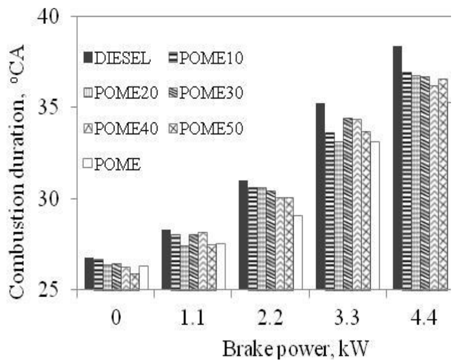

Fig. 15 Variation of combustion duration with crank angle [15]

The variation of the total duration of combustion with brake power for different fuels is shown in Fig 15. According to P. Chandrasekar at el. [15] The total duration of combustion is shorter for PSOME and its diesel blends while comparing with diesel fuel. Higher oxygen content in the PSOME and its diesel blends is believed to have enhanced flame velocity that resulted in reduction of combustion duration, compared to that of diesel.

5. Effect of injection pressure on single cylinder diesel engine performance and emission [19]

Chandraprasad et.al [17] considered pumpkin seed biodiesel obtain from pumpkin seed oil has been consider as potential fuel for C.I engine. In their study experiments have been conducted on 4 stroke, 3.72 kW single cylinder DI–CI engine at rated speed of 2880 rpm to analyze the effect of fuel injection pressure on the performance and emission characteristics. The engine was tested at different injection pressures (190, 210, and 230 bars) with B10 (10% biodiesel +90% diesel), B20 (20% biodiesel+80% diesel), B30 (30% biodiesel+70% diesel) were used for the test fuels and results were compared with B0 (diesel). Different fuel injection pressures were maintained by means of adjusting injector spring tension. The engine emission parameters like CO, HC and NOx were noted from exhaust gas analyser.

5.1 Performance characteristics

Brake specific fuel consumption

BSFC decreases with increase of injection pressure up to 210 bar further increase in the injection pressure beyond 210 bar has resulted in higher BSFC. It is noticed that, the values of BSFC are lower for an injection pressure of 210 bar compared to other injection pressure for all fuels. This could be due to fact that with increase in injection pressure, not only decrease the fuel droplet size but also increase the momentum of fuel droplets. The increase in momentum of fuel droplet could have got impinged on the cylinder inner wall and to develop same power, the fuel consumption should have increased. Among all fuels the diesel has lower BSFC value at 210 bar injection pressure. The BSFC of B20 was lower at all injection pressures.

Brake thermal Efficiency

It is observed that the BTE decrease with increase of concentration of biodiesel in the blend at all injection pressures. The B20 recorded significantly higher BTE, which are very close to diesel fuel BTE at all injection pressures. For all fuels BTE increases with injection pressure up to 210, further increase in injection pressure beyond 210 bar decrease the BTE. This may be mainly due to increased BSFC and higher momentum of fuel droplets.

5.2 Emission characteristics

Oxides of nitrogen

It is observed that, when the injection pressure increases NO_X emission increases up to 210 bars for all fuels. Further increase of injection pressure beyond 210 bar NO_X emission slightly decrease, which may be due to lower peak pressure arises due to lesser heat release rate during combustion leads to lesser spray penetration inside the combustion chamber. The increase of biodiesel blend concentration in diesel tends to increase the NO_X levels at all injection pressures, this may be due the presence of oxygen content in the biodiesel which enhances combustion process. The lesser values of NO_X were observed for diesel fuel compared to other. B10 also records comparatively lesser NO_X values than other blends at all injection pressures.

Hydro carbon

The un burnt HC emission tend to decrease with the increase of injection pressure up to 210 bar, further increase of injection pressure beyond 210 bar increase the un burnt HC emission. Increase of concentration of biodiesel in blend decreases HC emission at all injection pressures. The reason may be due to availability of more oxygen present in biodiesel causes complete combustion. The lower HC emissions are observed for all fuels at 210 bar injection pressure. The lower HC emissions are observed with B30 at all injection pressure compared to diesel.

6. Effect of N-butanol additive on performance of engine

Elanthiraiyan et.al [16] conducted an experiment a single cylinder, water cooled, four stroke direct injection compression ignition engine with a displacement volume of 661 cc, compression ratio of 17.5:1, developing 5.9 kW at 1800 rpm. Variable load tests are conducted for no load, 1.5, 3.01, 4.52- and 5.9-kW power output at a constant rated speed of 1800 rpm, with fuel injection pressure of 200 bars and cooling water exit temperature at 60^{0}C. Pumpkin seed oil with 20 and 40% blend with diesel and n-butanol as additives is used. The results show that various performance parameters of VCR engine with the use of different blends of n-butanol, pumpkin seed oil blends i.e.; B20 and B40 indicates that gradual decrease in SFC on increasing loads due to reduction in heat loss and better combustion at higher loads. Further brake thermal efficiency decreases with increasing ratio of pumpkin seed oil and additive n-butanol in diesel blends.

Conclusions

- The following conclusion are drawn from the review of feasibility of pumpkin seed oil and its methyl ester as alternative fuel to diesel.
- Potential of pumpkin seed is the order of 64 thousand tones in India. State of Orissa is the highest producer of these seeds.
- Viscosity of pumpkin seed oil is much higher than that of diesel. However, the viscosity of pumpkin oil methyl ester is well comparable with that of diesel.
- Density of the pumpkin seed oil and its methyl ester is higher than that of diesel.
- Calorific value of pumpkin seed oil and its methyl ester is lower than that of diesel.
- However pumpkin seed oil and its methyl ester contains sulphur, leading to emission of dangerous sulphur oxides, which contributes to acid rain.
- Brake thermal efficiency of 20% blend of pumpkin seed oil is well comparable with that of diesel.
- NOx, CO and HC emission of pumpkin seed oil-diesel blends are higher than that of diesel. Which attributes to inbuilt oxygen content of oil and its biodiesel.
- Brake thermal efficiency of 20% blend of PSOME with diesel is well comparable with that of pure diesel.
- NOx and smoke emission of PSOME and its blends with diesel are higher than that of pure diesel.
- CO and HC emission of PSOME and its blends with diesel are lower than that of pure diesel.
- Maximum cylinder pressure and heat release rate of PSOME is lower than that of diesel.
- Increasing injection pressure brake thermal

efficiency first increases than decreases. It decreases due to quenching of fuel at higher pressure.

- Performance of PSO and its biodiesel improved by adding additive N-butanol.
- Smoke emission for additives N-butanol in biodiesel reduces compared to that of neat biodiesel.
- Methyl ester produced from pumpkin seed oil may be used as 20% blend with diesel as alternate fuel.

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