ENERGY SOURCES, PART A: RECOVERY, UTILIZATION, AND ENVIRONMENTAL EFFECTS
2021, VOL. 43, NO. 12, 1511–1523
https://doi.org/10.1080/15567036.2019.1648593

Performance evaluation and emission characteristics of variable compression ratio diesel engine using Argemone Mexicana biodiesel

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ABSTRACT
The present work is focused on the production, emission and performance characteristics at variable compression ratios (CRs) on a compression ignition multi-fuel engine using Argemone Mexicana oil methyl ester and its blends with diesel (on a quantity basis) was observed and compared with the same. The feasibility of employing Argemone Mexicana oil methyl ester as a biofuel has been determined in the present work. Experiments have been conducted at a constant engine speed of 1,500 rpm and results are obtained at different CR of 14:1, 15:1, 16:1, 17:1, and 18:1. The ratios of blends used in this experiment are D100, AME5, AME10, AME20, AME35, AME50 and AME100, where the values relate to the share of the type of fuel given by the characters. The significance of compression ratio on the engine performance and emission has been investigated and presented for all the blends of biodiesel. The optimum results are obtained AME20 at CR17, which shows that the values of brake thermal efficiency, brake power, and specific fuel consumption are superior to that of both diesel and other blends. These blends, as fuel produces less emissions of CO, HC and marginally increase in NOx compared to that of diesel.

Abbreviations: AMO; Argemone Mexicana oil; AME5; 5% Argemone +95% Diesel; AME10; 10% Argemone +90% Diesel; AME20; 20% Argemone +8% Diesel; AME35; 35% Argemone +65% Diesel; AME50; 50% Argemone +50% Diesel; AME100; 100% Argemeon (Biodiesel); ASTM; American Society for Testing Materials; BTE; Brake thermal efficiency; BSFC; Brake specific fuel consumption; CI; Compression ignition; CO; Carbon monoxide; CO2: Carbon dioxide; NOx; Oxides of Nitrogen; SFC; Specific Fuel Consumption; VCR; Variable compression ratio

ARTICLE HISTORY
Received 23 December 2018
Revised 12 June 2019
Accepted 17 June 2019

KEYWORDS
Argemone mexicana; biodiesel; emissions; performance; variable compression ratio

Introduction

Conventional fuels have a lot of potential for utilizing in various applications and one among them is in automobile engines (Ganesan et al. 2018; Radhakrishnan et al. 2018). But those fuels are getting reduced every day due to an increase in consumption and also spoil the environment (Nagaraja, Sooryaprakash, and Sudhakaran 2015; Da Silva et al. 2011; Huang, Zhou, and Lin 2011; Zhou and Thomson 2009; Ramadhas, Jayaraj, and Muraleedharan 2004).

Hence, in the present context, it is vital to find alternative sources of energy. One among the alternate sources of energy is the biodiesel. It's environmentally friendly and also improves the mechanical efficiency of an engine when it is blended with diesel (Demirbas 2009; Shahid and Jamal 2008). Utilization of edible

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vegetable oils has issues like starvation as well as environmental problems in some countries. Therefore, employing non-edible oil such as Wild mustard (Brassica Juncea L.) Kusum, Pilu (Langhupilu),Mahua, Jatropha curcas, Rubeerseedoil, Pongamiapinnata (Karanja), Argemone Mexicana, Shorea robusta seed oil, Kokum (Garcinia indica) (Ashraful et al. 2014; Atabani et al. 2013; Fadhil, Saleh, and Altamer 2019; Suresh, Jawhar, and Richard 2018) could be an attractive option in a country like India for the production of bio-diesel. One of the eminent sources of non-edible oil is the oil derived from the seed of argemone. The biological name of this tree is known as Mexican poppy but "Argemone Mexicana" is often used instead. The Biodiesel obtained by transesterification of Argemone oil is called Argemone Mexicana oil Methyl ester (Sharma et al. 2012; Suresh, Jawhar, and Richard 2018) it is also expected that growth of Argemone Mexicana in the Indian subcontinent can lead to an increase in revenue from agriculture.

Singh, Duran, and Singh (2015) investigated using the diesel and blends of Argemone oil Methyl esters and it was found that the engine performance BTE, Brake specific fuel consumption (BSFC) and Brake specific energy consumption (BSEC) was improved. It also showed a better reduction in the emissions of CO, HC and Smoke opacity when compared to diesel. Studied various compositions of Argemone biodiesel blends with diesel fuel under different load condition (0%, 20%, 40%, 60%, 80%, and 100%) at constant speed. The results show that argemone biodiesel blend (AB10 and AB20) have improved fuel properties and also the performance of the engine when compared to diesel (Manish, Dave, and Mahalle 2014). Compares BTE with the brake power in Kokum oil biodiesel, rice bran oil biodiesel and their blends and it shows that BTE increases with an increase in brake power in all tested percentage of blends. But compared to the standard diesel the BTE is significantly lower. The emission of CO, HC is appreciably lower but the NOx emission is quite high (Attal and Mahalle 2014). Conducted experiments on blends of marine diesel and two types of biodiesel (sunflower and olive oil). A slight reduction in Specific fuel consumption (SFC) was found and also in CO, HC, NOx emissions (Kalligeros et al. (2003)). Investigated the waste cooking oil methyl ester at variable CR and the performance and emission characteristics were observed. In B40 the HC, CO, and NOx emission are higher at CRs, whereas the emission of CO_2 is reduced. At CR (CR21) for B40, BTE increases whereas the SFC and brake power slightly decreases (Muraleedharan and Vasudevan 2011, 2011). Observed that biodiesel of non-edible oil produces the best performances as that of the diesel which act as an exact alternative fuel to the diesel engine. At higher compression ratio the engine was operating smoother with lower emission and its performance was appreciable (Nagaraja, Sooryaprakash, and Sudhakaran 2015; Amarnath et al. 2014; Amarnath and Prabhakaran 2012; Anand et al. 2012;). Performed experimental investigations employing biodiesel for CRs 17:1, 18:1, and 19:1. They observed that the BTE increases proportionally to the CR. On the other side the emission of CO, HC decreases whereas the NO_X increases (Sayin and Gumus 2011). However, properties of the biodiesel were found to be better than diesel (Kale and Prayagi 2011). Studied the emission characteristics of the engine powered by biodiesel extracted from seeds such as karanja, jatropha, and putranjiva. Jatropha biodiesel showed promising results when compared with the other two (Ghosh, Haldar, and Nag 2008). Investigated a VCR diesel engine for 16 and 18. They reported that there has been a considerable amount of reduction in NO_X and soot emissions (Laguitton et al. 2007). Another study was made in VCR engine with Tamanu oil and diesel by varying CR from 14 to 18. It was detected at higher loads that BTE increases (Mohan and Kandasamy 2012; Mohanraj and Murugu Mohan Kumar 2012). Performed experimental studies employing Jatropha biodiesel for CR 16, 17 and 18 and concluded that the BTE increased correspondingly, while emission characteristics were found to be better at lower blend (De and Panua 2014).

Mahesh et al. (2015) observed that the amount of catalyst, the ratio of methanol to oil in moles and reaction temperature on the yield of the heterogeneous catalyst production were symbolic factors in methyl ester production (biodiesel) from waste cooking oil. Sirisomboonchai et al. (2015) determined the ratio of methanol to oil in moles, the amount of catalyst and reaction temperature on the yield of the calcined scallop shell catalyst production were consequential factors in the production of methyl ester production (biodiesel) from waste cooking oil. Gurunathan and Ravi (2015) reviewed biodiesel production from waste cooking oil by using copper doped zinc oxide (CZO) nanocomposite as heterogeneous catalyst. The copper doped zinc oxide nanocomposite added on the percentage of biodiesel yield. AshokKumar, Chandramouli, and Mohanraj (2015) inferred from the research work that the brake thermal efficiency is slightly more in biodiesel than in standard diesel for all compression ratios. It also showed that brake specific fuel consumption of blended fuel is very near to the standard diesel. A significant decrease in the emissions is observed in biodiesel rather in standard diesel. Kommana, Banoth, and Kadavakollu (2016) carried out experimental studies using diesel blended with the palm kernel oil and eucalyptus oil in 5%, 10%, and 15% blends. Several tests were carried out at several loads (0, 6, 12, 18 and 24 N m). They inferred that there is 41.09% reduction in CO, 42.99% reduction in HC, 9.02% increase in NOx emissions and 37.05%reduction in smoke for B15 blend at 100% load conditions. Naik and Maheswara Rao (2016) evaluated the performance of a single cylinder four-stroke diesel engines with variable compression ratios of 16.5, 17.0, 17.5, 18.0 and 19.0. The mechanical efficiency is directly proportional to load. Emission characteristics were analyzed with respective to air–fuel ratios of 16.5, 17.0, 17.5, 18.0 and 19.0 and it resulted as CO, CO_2, HC, SOx and O_2 were decreasing for the compression ratio of 17 compared to other compression ratios due to efficient combustion. NO_x is lower in the case of compression ratio 17, the NO_x emission increases for all the compression ratios due to increase of cylinder temperature. At CR 16.5 the mechanical efficiency is found to be lower, it is high for higher compression ratios. As increase in compression ratio brake thermal, brake power, specific fuel consumption increases. Lal and Mohapatra (2017) carried out experimental investigations using the producer gas it was noticed the BSFC in dual fuel mode was 34.40–68.75% higher than diesel mode at 3.2 kW brake power. For a compression ratio of 18, BSFC was found to be 0.33kg/kWh in diesel mode and 0.54 kg/kWh in dual fuel mode. Emission of CO was 81–84% dominant than diesel mode on the other hand NOx emission was 35.29–56.09% lesser in dual fuel mode. The SOx emission in dual fuel mode was 54.54% less as compared to the diesel fuel mode. Sivaramakrishnan (2017) investigated experimental studies with fuels 20% 25% 30% of karanja blended with diesel were reviewed and compared with standard diesel at a compression ratios of 15:1, 16:1, 17:1, 18:1. It was analyzed using B25 at CR 18. BTE increases with the increase in CR. At compression ratio 18, BTE for B25 is 30.46% which is 5% higher than diesel. Experiment resulted in the minimum emission of HC at B20 is 16ppm which is comparatively less than the diesel which is 96ppm.CO emission is resulted less in B25 than standard diesel. Specific fuel consumption is inversely proportional to compression ratio. B25 at CR 18 resulted in brake specific fuel consumption of 0.28 kg/k against of 0.29kg/k diesel. Kataria, Mohapatra, and Kundu (2018) performed analytical studies on performance and emission characteristics at CR 15 & 17.5 which shows Blend 40 at CR 17.5 exhibits maximum thermal efficiency at full load which is more than that of standard diesel. Brake specific fuel consumption is decreased in all the compression ratios with increase in loads. Emissions in the HC are inversely proportional to concentration of the biodiesel blends. Yadav et al. (2018) carried out experiments using the different blends ofAB5, AB10, AB15, AB20, AB25, AB30, and AB50.It showed that AB30 was optimal Blend which reduces HC and CO emissions up to 35.10% and 30% as compared to standard diesel. The emissions of NOx, CO2, and O2 were raised up to 25–30%, 9–20%, and 8–20%, respectively. Verma et al. (2019) analyzed the variation of EGR with respect to CR that was varied from 16.5 to 19.5. The NOx emissions were reduced by 3.4%, 14.7% and 22.9% with the use of 5% 10% and 15% cold EGRs, respectively, with respect to diesel. This also results that hot EGR has positive effects over cold EGR on the engine performance and emission characteristics of diesel-biogas DF engine. Karikalan et al. (2019) carried out investigations on a diesel engine for various compression ratios from 16.5, 17.5, 18.5 and 19.5:1 to determine the emissions and performance parameters. It is observed that a significant reduction in hydrocarbon (HC), minor increase in NO_X and improved brake thermal efficiency for high compression ratios to a biodiesel blends compared to that of diesel. Balasubramanian and Subramanian (2019) examined the results for CR varying from 19:1 to 21:1. The change in CR from 19:1 to 21:1 for the biodiesel enhanced the brake thermal efficiency by about 9.5% and 4.63% at full load, compared to the base value CR of 19:1. However, NOx emission increased to 8.71 and 7.73g/kWh, respectively, for CR of 19 and 9.25.

Novelty of the research work

This work studies the effect of Argemone mexicana oil biodiesel as a potential alternate to diesel. Argemone mexicana has low free fatty acid compared to other non-edible and it is trouble-free available in India and world. Its blends are employed owing to toxic nature, free from sulfur, biodegradable and free of aromatics.

From the reveiw of literature, it is observed that several researchers have done experimental tests to assess the production, emission and performance characteristics of an argemone oil-based biodiesel in a fixed compression ratio diesel engine. No work has been reported so far pertaining to the utilization of Argemone mexicana biodiesel in a variable compression ratio (VCR) engine. The need for switching over to VCR engine is that; it provides better fuel efficiency, upto 30% reduction in fuel consumption, better control at peak cylinder pressure, ability to use multi-fuel and reduction in the exhaust emissions when compared to that of a constant compression ratio diesel engine. Hence, the present work is focused on the VCR engine performance and emissions characteristics of the same.

Methodology

Biodiesel blends in the range of AME5, AME20, AME35, AME50, and AME100 were prepared from biodiesel based on argemone oil and pure mineral Diesel. Tests were done to find out the variation of viscosities with temperature using a Redwood viscometer. The engine was run at a constant speed of 1,500 rpm. Compression ratio variation is done so as to get six points of evaluation. The trials were repeated thrice utilizing different blends. The differences in result were within limits of ±1% in all the cases.

Experimental setup

Schematic diagram of the experimental setup is shown in Figure 1. The setup consists of a four-stroke single-cylinder research engine which is water-cooled and multi-fuel variable compression ratio with a data acquisition system. The engine (was) mounted on the bed in the test cell. The dynamometer (eddy current water-cooled with loading unit) (was)connected with the engine flywheel with the help of a drive plate in the flywheel and a dynamometer flange coupled with the shaft. Uncertainty in the loading is ± 0.5%. After the engine is mounted on the bed, the other components like the sensors and other fuel system components are mounted. The research engine has a specifically designed tilting cylinder block arrangement which enables the engine to vary the CR without discontinuing the engine and altering the combustion chamber geometry. The engine employed in this research is equipped with an instrument which helps to measure the interface flow, fuel flow, temperatures and load during the experiment. It also has a standalone box with two fuel tanks for testing multi-fuel (Diesel & Argemone oil and its blends). Again to this, it is mounted with a manometer, fuel measuring unit, transmitters, process indicators and engine indicators wherein manometer, fuel measuring and transmitter helps to measure the airflow and fuel flow in the engine. The cooling water and calorimeter water flow are measured by using rotameters. For analyzing the online performance evaluation of the Engine Performance Analysis software package known as "Engine soft" is used for this purpose. The variable CR engine is activated by using diesel and when the stable condition is reached, the engine is loaded with part load or full load. An exhaust gas emission analyzer (AVL DIGAS) was used to measure CO, HC, CO_2, O_2, and NO_x. The cooling water is used with a flow rate of 69ml/sec and thus cooling water temperature is stabilized at 41°C in the engine socket. The engine was run at a constant speed of 1,500 rpm. Performance and emissions were measured with an engine operating with pure Diesel. Blends tested were ranging from 0% (mineral diesel) to 100% (Argemone oil) by 5%, 20%, 35%, 50%, and 100%. These mixes were then subjected to emission and performance tests on the engine. For all the experiments, performance and exhaust gas data were analyzed and the results are reported below. The complete specification of the VCR test rig engine is shown in Table 1.

Evaluation of fuel properties

Argemone Mexicana is (an) herbaceous therapeutic plant having a place with the group of Papaveraceae. It is indigenous to Mexico. Usually, it is dispersed all through the more sultry parts of India, up to 1500 meters height as a weed. Argemone Mexicana is also known by its botanical name called "Mexican Poppy". The Argemone Mexicana fruits were collected from the Konkan area and along coastal areas and adjacent lowland forests coastal area. The fruits were dried and dehulled to obtain the seeds. Raw Argemone

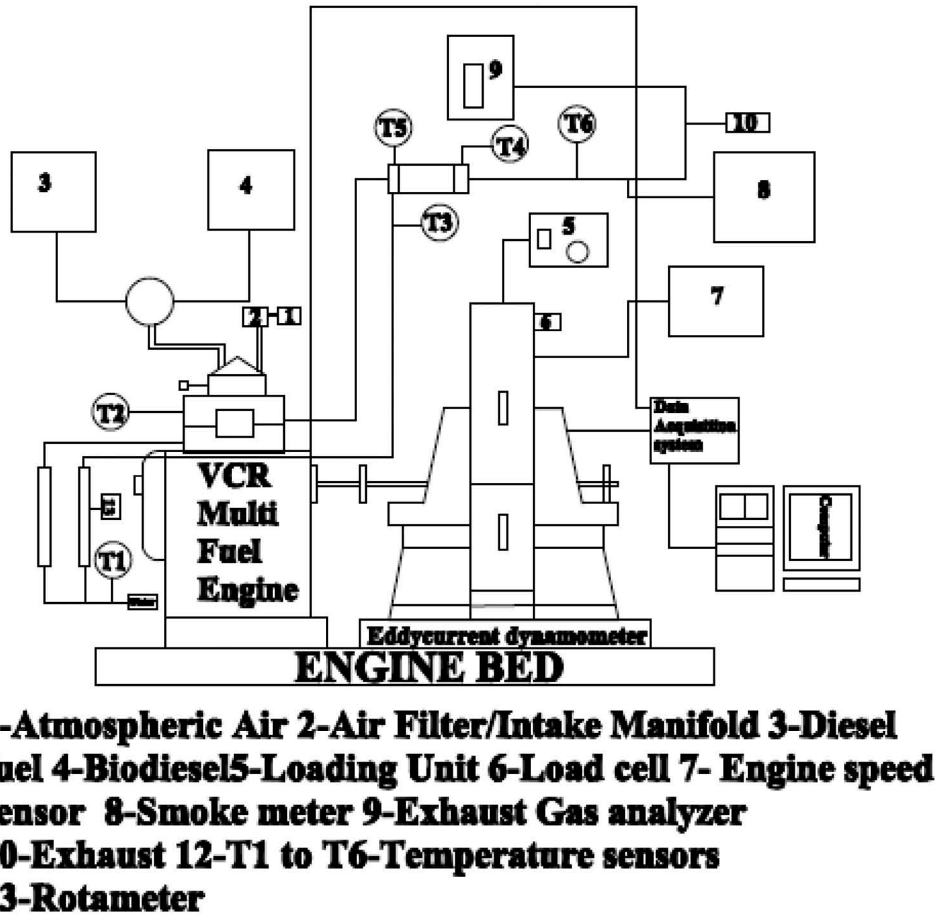

Figure 1. Schematic of the experimental setup.

Table 1. Engine specifications.

Type	Single cylinder, Four stroke Multifuel Variable compression ratio diesel engine (Computerized)
Product	Research engine test setup engine-Kirloskar Make
Bore	87.50 mm
Speed	1500 rpm
Length	110 mm
Compression ratio	12–18
Swept volume	661.45 cc
Dynamometer	Type eddy current, water cooled, with loading unit

Mexicana cannot be used as it is, so the trans-esterification process Figure 2 is done by using the alcohol/catalyst mix in the closed vessel. Here potassium hydroxide is used as the catalyst, so for every 50 ml of Methanol, 2 gramof KOH is added. The argemone oil is initially heated to 60°C, and then made to react with methanol and stirred for about 15 min till it completely dissolves. After the Trans esterification process, the mixture was moved on to a separation flask where the mixture is left to settle down for 24 hours. There will be two different layers formed which is the biodiesel at the top layer and glycerine at the bottom layer Figure 3. The top layer is further moved on to the process called washing as shown in Figure 4 in order to reduce the pH value. The process is repeated about three times until the pH value reduces to 7. By using the washing method pure biodiesel is obtained. The properties were evaluated for the blended proportions of biodiesel and diesel (Table 2 and 3).

Figure 2. Transesterification process.

Figure 3. Separation process of biodiesel and glycerin.

Figure 4. Washing process of biodiesel.

Table 2. Properties of Argemone biodiesel.

Test Description	Ref. Std. ASTM 6751	Limit	Diesel D100	Argemone oil AME5	AME100
Density(Kg/m^3)	D 1448– 1972	850–900	831	850	882
Viscosity(cSt)/ mm^2/sec	D445-73	3.0–6.1	3.2	2.59	5.7
Calorific value(MJ/Kg)	D 6751	34–45	44.5	43.2	39.1
Ash Content (% wt)	ASTM D482	0.1 max	ND	ND	ND
Flash Point (°C)	D 93	120–170	76	66	165
Fire Point (°C)	D 93	130–185	78	70	180

Table 3. Details of uncertainties.

S.No	Measured/Estimated Parameters	Uncertainty
1	Carbon dioxide(CO_2)	± 0.5%
	Carbon monoxide (CO)	± 0.1%
	Hydrocarbon(HC)	± 0.005%
	Oxides of Nitrogen(NO_x)	± 0.016%
	Oxygen(O_2)	± 0.04%
2	Brake power (BP)	± 0.5%
3	Brake thermal efficiency(BTE)	± 1.04%
4	Crank angle	± 1°
5	Load	± 0.1kg
6	Specific fuel consumption(SFC)	± 1.05%
7	Temperature	± 0.15C

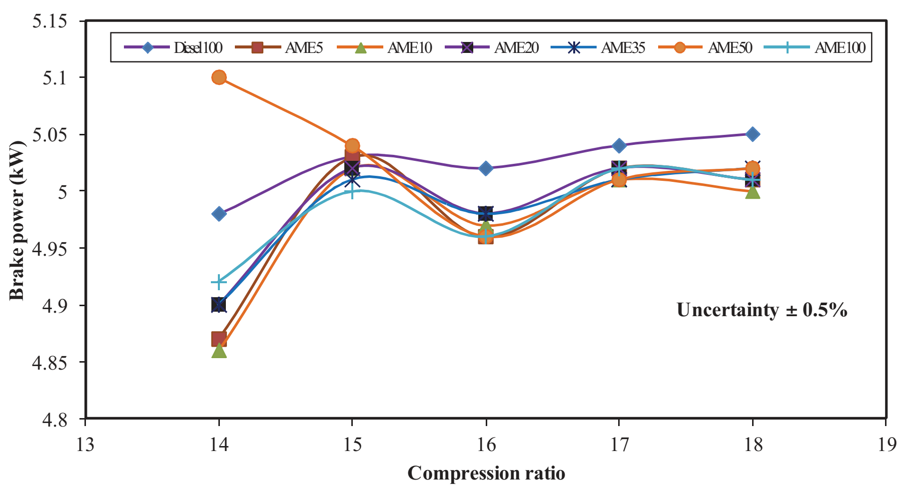

Figure 5. Variation of break power with compression ratio for various blends.

Results and discussion

Engine performance

Figure 5 depicts the variation of brake power with the compression ratio (CR). Figure 5 show that there is a considerable decrease corresponding to the blends AME5, AME10, AME20, AME35, AME50, and AME100 when compared to standard diesel. When compared to other blends the brake power is higher for AME20 at CR 16, 17 and 18. The brake power for AME20 is 5.02kW at CR 17 whereas for diesel it is 5.04. There is a decrease of 0.396% brake power for AME20 when compared with diesel at CR 17. A decrease in brake power at higher CRs is reported owing to the conversion of chemical energy to mechanical energy

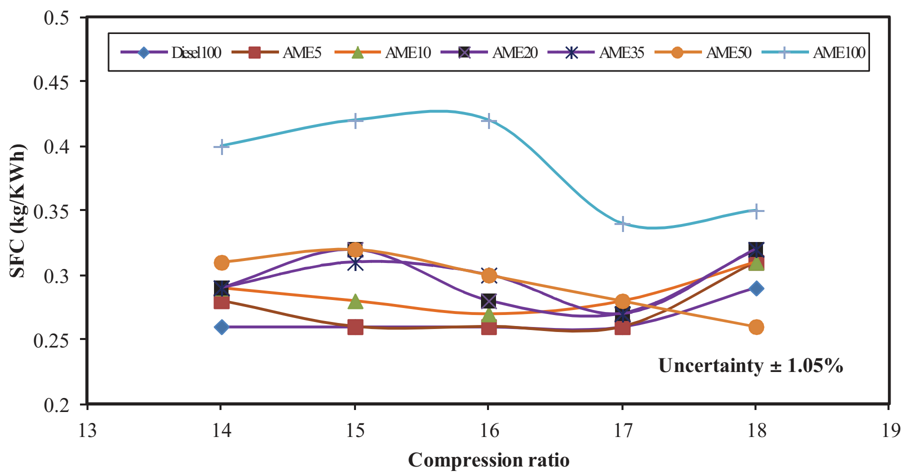

Figure 6. Variation of specific fuel consumption with compression ratio for various blends.

(Muraleedharan and Vasudevan 2011; Nagaraja, Sooryaprakash, and Sudhakaran 2015). In the present study, at the CR of 17, the BP is found to be 5.01 (kW), which is similar to the one reported by Nagaraja, Sooryaprakash, and Sudhakaran (2015); The brake power decreased as a result of the lower heating value of blends and unstable combustion (Amarnath et al. 2014; Muraleedharan and Vasudevan 2011; Nagaraja, Sooryaprakash, and Sudhakaran 2015). The uncertainty in the BP estimation is ± 0.5%.

The variation in SFC with respect to compression ratio is depicted in Figure 6 SFC of AME20 blend is noticed to be minimal than that of other blends at CR 17 and 18. This can be attributed to the fuel viscosity, density, and heating value of blended fuels (Amarnath and Prabhakaran 2012; Anand et al. 2012; Sivaramakrishnan 2017). It appears that the SFC for blend AME20 is minimal at compression ratio 17. The SFC decreases with an increase in compression ratio. The SFC of the blend AME20 at the compression ratio of 17 was 0.27 kg/kWh whereas for diesel it is 0.26 kg/Kwh. It was observed that the SFC increased by 3.84% when compared with diesel at compression ratio 17. The SFC increases with an increase in the percentage of blends added which can be attributed to the decrease in calorific value of the superior blends. It has been observed that from literature fewer values of SFC are required for the better performance of the engine. The research work carried out by (Amarnath and Prabhakaran 2012; Anand et al. 2012; Sivaramakrishnan 2017) show the SFC of 0.3 kg/kWh, 0.28 kg/kWh and (0.32 kg/kWh), respectively, and concluded that lower SFC leads to increased efficiency of an engine. In the present study, at a CR of 17, SFC of 0.27 kg/kWh is reported, which is less the one reported in the literatures. The uncertainty in the determination of SFC is ± 1.05%.

The variation in BTE with respect to CR is shown in Figure 7. It was noted that BTE corresponding to the blend AME20 is higher at CR 17. It was found that the BTE increases with the increase in CR. The BTE for blend AME20 at CR 17 was found to be 30.18% whereas for diesel it was 33.3%. The BTE is 9.36% less than for the standard diesel, because of the higher viscosity of blend AME20, which show the ways to reduced atomization and hence poor combustion (Amarnath and Prabhakaran 2012; Anand et al. 2012; Sivaramakrishnan 2017). The BTE obtained in the present study corresponding to the CR of 17 is 30.5%. This is similar to the reported by Sivaramakrishnan (2017) (30.2%), Amarnath and Prabhakaran (2012) (30.1%), Anand et al. (2012) (27.8%) and Muraleedharan and Vasudevan (2011) (29%). The uncertainty in the determination of BTE is ± 1.04%.

Emission characteristics

Figure 8 shows the emission of a CO of various blends (AME 5, AME 10, AME 20, AME 35, AME50, and AME 100) with diesel at various CRs. It was found that AME 20 blend has lower CO emission at

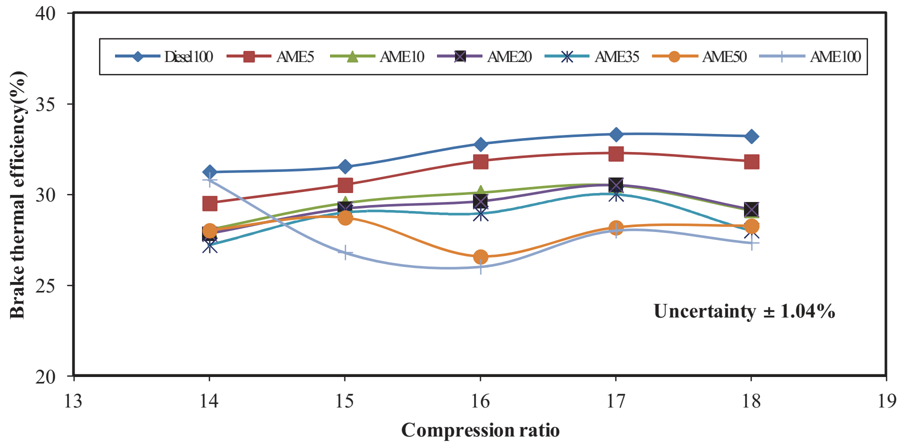

Figure 7. Variation of brake thermal efficiency with compression ratio for various blends.

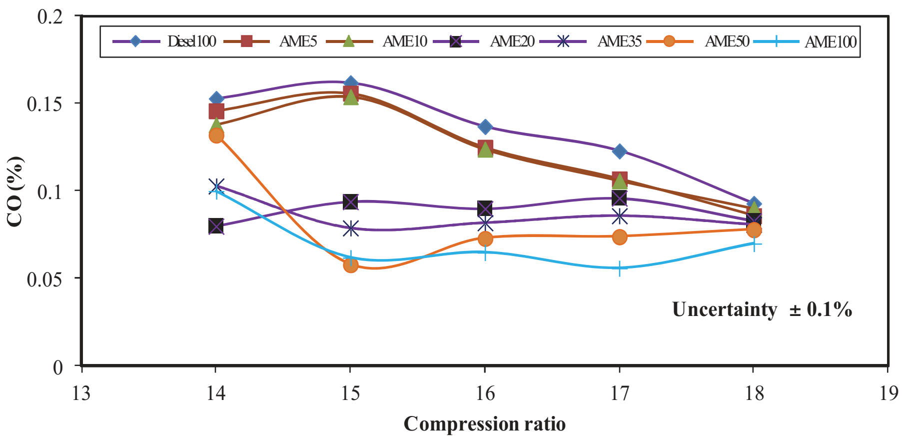

Figure 8. Variation of carbon monoxide with compression ratio for different blends.

CR 17 when compared with diesel.CO emission of blend AME20 at a CR of 17 is 0.096% whereas for diesel is 0.123%. It was observed that the emission of CO decreased by 21.9% as compared to standard diesel. The percentage of CO decreases is due to the higher temperature in the combustion chamber for a complete combustion to take place (Anand et al. 2012, 2012; Balasubramanian and Subramanian 2019; Muraleedharan and Vasudevan 2011, 2011; Nagaraja, Sooryaprakash, and Sudhakaran 2015; Sivaramakrishnan 2017). Percentage of CO is found to be 0.096 in the present study at CR 17 which is slightly lower than the results of the studies reported by Nagaraja, Sooryaprakash, and Sudhakaran (2015)(0.15%) Anand et al. (2012) (0.4%) and Muraleedharan and Vasudevan (2011) (0.14%). The uncertainty in the estimation of CO emission is ± 0.1%.

Figure 9 shows the emission of a hydrocarbon of various blends (AME 5, AME 10, AME 20, AME 35, AME50, and AME 100) with diesel at various CRs. It was found that AME 20 blend has lower hydrocarbon emission at CR 17 when compared with all other blends at CR 18. This is due to the viscosity of the fuel and the fuel spray quality (Parida and Rout 2017; Singh et al. 2017; Balasubramanian and Subramanian 2019; Muraleedharan and Vasudevan 2011). It was found that hydrocarbon emission increased with increase in CR. The hydrocarbon emission of the blend AME20 at CR 17 was 66 pm whereas for diesel it is 88 pm. The hydrocarbon emission was decreased by 25% when compared with diesel at CR 17. HC emission is

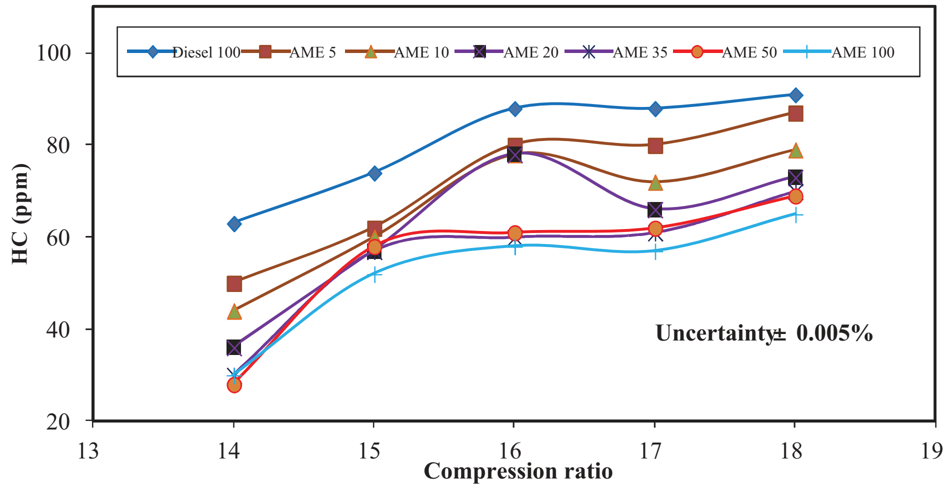

Figure 9. Variation of hydrocarbon with compression ratio for various blends.

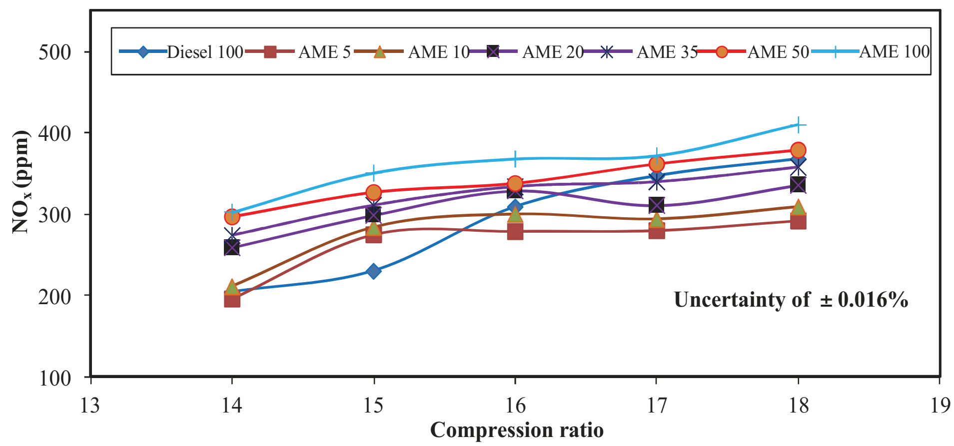

Figure 10. Variation of nitrogen oxides with compression ratio for various blends.

observed as 66 ppm for a CR 17 compared to 90 ppm reported by Anand et al. (2012). The decrease in hydrocarbon emission is due to the increase in temperature at the compression stroke, where the increase in combustion temperature which leads to better combustion (Amarnath and Prabhakaran 2012; Anand et al. 2012; Sivaramakrishnan 2017). The uncertainty in the determination of HC emission is ± 0.005%.

Figure 10 demonstrates the emission of NO_X for blends (AME5, AME10, AME20, AME35, AME50, and AME100) and diesel at various CR. It was deduced that AME20 has lower NO_X emission at Compression ratio 17 when compared to compression ratios15 and 16. Emission of NO_X happens due to the formation of high temperature inside the cylinder (Anand et al. 2012; Balasubramanian and Subramanian 2019; Muraleedharan and Vasudevan 2011). It can be observed that as compression ratio increases, emission of NO_X also increases. As the amount of biodiesel in the blend is increased, the emission of NO_X will also increase, because of an excess amount of oxygen in the biodiesel (Singh et al. 2017). The NO_X emission at the CR of 17 is observed to be 311 ppm whereas for diesel it is 347ppm. The NO_X emission decreased by 10.37% when compared with diesel at CR 17. NOx emission is observed to be 311 ppm at CR of 17 compared to that of 610 ppm reported by Muraleedharan and Vasudevan (2011). It is also observed that oxygen concentration in the exhaust gas at higher CR is less, hence lower the NO_X formation. Experimental results show that the exhaust temperature decreases with increase in biodiesel blend ratio, which leads to the decrease in NO_X formation. The uncertainty in the analysis of NOx emission is ± 0.016%.

Conclusions

The performance evaluation and emission characteristics of a variable compression ratio ignition engine, using the biodiesel-based argemone oil and its blends have been studied and compared with that of diesel. Studies were carried out for different compression ratios. The experiment resulted in different thermal as well as emission characteristics for compression ratios 14:1, 15:1, 16:1, 17:1 and 18:1 at a constant speed of 1,500 rpm. The following results were examined after conducting the experiment.

- The brake power AME 20 is higher than that of all the blends of argemone oil when the compression ratio is increased, which is slightly lesser than the standard diesel.
- The brake thermal efficiency is higher for AME20 with respect to an increase in compression ratio and percentages of biodiesel blends; but slightly lesser than that of the standard diesel.
- Specific fuel consumption decreases when the compression ratio is increased. At CR17 AME20 exhibits the reduction in the specific fuel consumption.
- While compared with standard diesel, the emission of CO and HC is highly reduced when the percentage of biodiesel blends and compression ratio are increased, respectively. But, the emission of NO_X is slightly higher when the CR and percentage of blends increases.
- The performance and emission characteristics were found to be better for AME 20% than diesel and other blends at optimum compression ratio of 17.
- Hence, it was observed that the AME 20% can be used as an alternative fuel without any modification in an engine and also proved that an optimum compression ratio enhances the engine performance and reduce emissions.

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