Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 7 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Study of Combustion and Performance Characteristics on a Single Cylinder DI Diesel Engine with Jatropha and Pongamia Methyl Ester Blends

By M. Anandan, S. Sampath & Natteri M. Sudharsan
Sri Venkateswara College of Engineering, India

Abstract- Biodiesels are produced from various organic materials such as plants, fossils and bio wastes etc. The present work is a proposal for the study of combustion characteristics in a single cylinder DI diesel engine with a bio-fuel derived from Jatropha and Pongamia seed oil for supporting industrial aspects in India. Tests were conducted to study the engine characteristics such as heat release rate, peak pressure, ignition delay and brake thermal efficiency were studied for part load and rated load with different compression ratios 17.5:1, 19:1 and 20:1. Experimental results conclude that engine operating at a compression ratio 20:1 is found to be more effective with Jatropha and Pongamia blends. Combustion characteristics reveals maximum cylinder pressure occurs at PME20% as an optimal blend ratio. Ignition delay were reliable for shorter angle at 12.6° for PME20% blend. Performance characteristics suggests that brake thermal efficiency was increased for JME30% blend ratio.

Keywords: compression ratio, biodiesel blends, combustion, ignition delay, brake thermal efficiency.

GJRE-A Classification : FOR Code: 290501

STUDYOFCOMBUSTIONANDPERFORMANCECHARACTERISTICSONASINGLECYLINDERDIDIESELENGINEWITHJATROPHAANDPONGAMIAMETHYLESTERBLENDS

Strictly as per the compliance and regulations of:

© 2014. M. Anandan, S. Sampath & Natteri M. Sudharsan. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons.org/licenses/by-nc/3.0/), permitting all non commercial use, distribution, and reproduction inany medium, provided the original work is properly cited.

Study of Combustion and Performance Characteristics on a Single Cylinder DI Diesel Engine with Jatropha and Pongamia Methyl Ester Blends

M. Anandan [α], S. Sampath [σ] & Natteri M. Sudharsan [ρ]

Abstract- Biodiesels are produced from various organic materials such as plants, fossils and bio wastes etc. The present work is a proposal for the study of combustion characteristics in a single cylinder DI diesel engine with a bio-fuel derived from Jatropha and Pongamia seed oil for supporting industrial aspects in India. Tests were conducted to study the engine characteristics such as heat release rate, peak pressure, ignition delay and brake thermal efficiency were studied for part load and rated load with different compression ratios 17.5:1, 19:1 and 20:1. Experimental results conclude that engine operating at a compression ratio 20:1 is found to be more effective with Jatropha and Pongamia blends. Combustion characteristics reveals maximum cylinder pressure occurs at PME20% as an optimal blend ratio. Ignition delay were reliable for shorter angle at 12.6° for PME20% blend. Performance characteristics suggests that brake thermal efficiency was increased for JME30% blend ratio.

Keywords: compression ratio, biodiesel blends, combustion, ignition delay, brake thermal efficiency.

I. Introduction

Supplement to the petroleum fuels becomes a common practice and needful for reducing the usage of fossil fuel resources. Enhancing the production of vegetable oil supports the fuel demands. Biodiesel is methyl or ethyl ester of fatty acid derived from vegetable oils (both edible and non-edible) and animal fat. The main resources for biodiesel production can be non-edible oils obtained from plant species such as Jatropha curcas, Pongamia pinnata, Calophyllum inophyllum, hevea brasiliensis (Rubber) etc. Biodiesel can be blended in any proportion with mineral diesel to produce a biodiesel blend or can be used in its pure form like petroleum diesel [1]. Biodiesel operates in compression ignition (diesel) engine, and essentially require very little or no engine modifications because biodiesel has properties similar to neat diesel [2]. It can be easily stored and transported because of its higher flash point temperature [3]. The use of biodiesel in conventional diesel engines results in substantial reduction in emission of unburned hydrocarbons, carbon monoxide and particulate matters [4]. Environmental factor is the major concern for an alternate fuel. In India adoption of Euro V equivalent emission norms are under consideration. Implementation of emission norms will focus on to reduce the sulphur content and increase the Cetane number of the fuel [5]. Biodiesel derived from rice bran oil, Mahua oil, Neem oil, Jatropha oil, Pongamia oil etc.are suitable alternative fuels for DI diesel engine. The performance of diesel engine depends on blends percentage, Ignition timing and it reduced with increasing the blends percentage beyond 50% [6], [7]. The performance and emission characteristics study was carried out for non-edible vegetable oil such as linseed oil, rice bran oil and its methyl ester. Operational and durability problems were occurred because of high viscosity, low volatility and poly unsaturated character to overcome this vegetable oil methyl ester blends were used instead of straight vegetable oil [8]. Higher viscosity of vegetable oil affects the atomization results in poor combustion and it is prevented by transesterification process. 25 percentage of cotton seed methyl ester blends performance almost same as the neat diesel while used as a fuel in diesel engine [9]. Processed cooking oil was used as a biodiesel through transesterification process. The effect of cooking oil diesel blends like B20, B50, and B100 was compared with neat diesel. 20% of blends produce the lowest carbon monoxide emission than 50 percentage of blends exclude at high engine speed [10]. Straight vegetable oil (Jatropha) used in diesel engine reduce the brake thermal efficiency and increase the smoke. Use of vegetable oil blend with methanol increase the brake thermal efficiency similarly smoke was significantly reduced [11]. Ignition delay, peak pressure and heat release rate were studied compression ignition diesel engine was operated with duel fuel such as karanja methyl ester and hydrogen fuel. Ignition delay increased at full load and it decrease considerably with lower loads. During the combustion process, karanja methyl ester burns with hydrogen results it increase the

Author α: Associate professor, Department of Marine Engineering, Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India. e-mail: anandanmoothy@gmail.com
Author σ: Professor, Department of Automobile Engineering, Rajalakshmi Engineering College, Chennai, Tamil Nadu, India.
Author ρ: Professor, Department of Mechanical Engineering, Rajalakshmi Engineering College, Chennai, Tamilnadu, India.

© 2014 Global Journals Inc. (US)

heat release rate. Low viscosity of fuel with hydrogen burns quickly and produces high pressure [12]. A cold pressed cashew nut shell liquid blend with diesel was used as an alternative fuel in internal combustion engine. 20 percentages of CNSL blends produce closer value of brake thermal efficiency as neat diesel. Cylinder pressure and heat release rate gets reduced with increasing the Cashew Shell Nut Liquid (CSNL) proportions. Operating engine with 40 percentage of CSNL blends engine knocking was observed [13]. Mahua oil and its blend were used as a fuel in direct injection diesel engine and the performance, emission and combustion characteristics was studied. Ignition delay, cylinder pressure and heat release rate was taken for combustion analysis. The output results for Mahua blends almost comparable with diesel hence; it can be used in diesel engine without any modifications [14]. The present work was approached to study the effect of increase in compression ratio (CR) of a conventional diesel engine operated with different percentage of Jatropha methyl ester and Pongamia methyl ester blends with neat diesel. Peak pressure, heat release rate and ignition delay characteristics for different compression ratio and different biodiesel blends were studied. Also the effect CR with brake thermal efficiency was studied for different percentage of biodiesel blends.

a) Esterification Process

Transesterification is a suitable method of utilizing vegetable oils in Compression Ignition engine without any long-term operational and durability problems. Vegetable oils can play a vital role in power generation for developing countries. Esterification is a chemical treatment process performed for treating vegetable oils [15]. Crude Jatropha and Pongamia seed oil was used for Transesterification process to convert crude oil into methyl ester oil. The Esterification process parameters such as reaction condition, type of alcohol, amount of catalysts, reaction time and temperature were controlled by manual mode. Single stage base catalyzed Transesterification was used for Jatropha and Pongamia. Methanol used as a regeant; H_2SO_4 and KOH used as a catalyst for base reaction.

b) Biodiesel Properties

The fuel properties of Jatropha methyl ester (JME) and Pongamia oil methyl esters (PME) blends with diesel are shown in Table1.The biodiesel properties such as density (kg/m3), calorific value (kJ/kg), viscosity (cSt), flash point (0C) was improved by Transesterification process. The property of biodiesel was tested as per IS15607:2005 standards. The methyl esters of Jatropha and Pongamia oil properties relatively closer with neat diesel. From the experimental results, these bio fuels can be used to operate the existing engine without any modifications. Compare with diesel, Jatropha and Pongamia blends contain oxygen molecules in the fuel. Hence complete combustion of fuel in the engine inhibits with the presence of oxygen ions in the biodiesel. Flash point for biodiesel was high, so it is safe to store compare with diesel. Small amount of biodiesel (Jatropha and Pongamia) added with the diesel increase the flash point of diesel blends.

II. Experimental Setup and Procedure

AVL software and data acquisition system was used to analyze the combustion characteristics of an engine as shown in Fig. 1. AVL 365C angle encoder was used to measure the crank angle position. AVL GH14D Pressure transducer was used to convert cylinder pressure value into analog signal form to the data acquisition system. Specification of the DI diesel engine was shown in Table 2. Experimental investigations of Jatropha methyl ester and Pongamia methyl ester were carried out in a four stroke single cylinder air cooled direct injection 4.4 kW at 1500 rpm diesel engine as a bore of 87.5 mm and stroke length of 110 mm as shown in Fig. 2 and Fig. 3. Engine test was performed with neat diesel; biodiesel blends (10%, 20% and 30%) for different compression ratios of 17.5:1, 19:1 and 20:1. Electric Dynamometer consists of electrical power bank it applies loads 0%, 25%, 50%, 75%, 100% on engine and it is controlled with the aid current and voltage values. The performance of biodiesel blends experimental values are compared with neat diesel.

III. Error Analysis

Error analysis was performed to indentify the accuracy of the measuring instruments. The percentage of uncertainties of a measuring instruments as given in Table. 3 Percentage of uncertainties present in experiments is = square root of ((uncertainty of pressure transducer)2 + (uncertainty of angle encoder)2 + (uncertainty of K-type thermocouple)2 + (uncertainty of stop watch)2 + (uncertainty of manometer)2 + (uncertainty of burette)2)+ (uncertainty of load cell)2 = square root of ((0.20)2 + (1)2 + (0.4)2 + (0.2)2 + (0.5)2 + (0.15)2+ (0.21)2) = square root of (1.566) = ±1.25%.

IV. Results and Discussion

a) Cylinder Pressure

i. *Pongamia Methyl Ester Blends*

The variation of cylinder pressure with crank angle for PME blends at different compression ratio as shown in Fig. 4a-c. For compression ratio of 17.5, peak pressure occurs at 67.49 bar at CA of 50 after TDC for diesel and 67.9 bar at CA of 60after TDC for PME10%, 67.67 bar at CA of 60 after TDC for PME20%, 67.68 bar at CA of 70 after TDC for PME30%. For 19 compression ratio, peak pressure occurs at 75.72 bar at CA of 70 after TDC for diesel and 75.78 bar at CA of 60 after TDC, 75.25 bar at CA of 60 after TDC, 76.94 bar at CA of 70

© 2014 Global Journals Inc. (US)

after TDC for PME10%, PME20%, PME30% respectively. For 20 compression ratio, peak pressure occurs at 75.61 bar at CA of 60 after TDC for diesel and 76.62 bar at CA of 60 after TDC, 75.83 bar at CA of 70 after TDC, 75.63 bar at a CA of 70 after TDC for PME10%, PME20%, PME30% correspondingly. It is observed from the figure that biodiesel blends had a higher peak pressure than diesel. The Combustion peak pressure increased with increasing the compression ratio.

ii. *Jatropha Methyl Easter Blends*

The variation of cylinder pressure with crank angle for JME blends at different compression ratio as shown in Fig. 6a-c.For compression ratio of 17.5, JME10%, JME20%, and JME30% combustion pressure of 69.28 bars at CA 70 after TDC, 70.67 bar at CA of 70 after TDC, 69.42 bar at CA of 60 after TDC respectively. For compression ratio of 19, JME10%, JME20%, J30% combusts pressure of 77.12 bar at CA 60 after TDC, 79.19 bar at CA of 80 after TDC, 78.85 bar at CA of 60 after TDC respectively. For compression ratio of 20, JME10%, JME20%, JME30% combustion pressure of 76.76 bar at CA 70 after TDC, 77.98 bar at CA of 60 after TDC, 77.83 bar at CA of 50 after TDC respectively. The peak pressure forJME20%, atCR of 20 was 3.57bar, for PME30% at CR of 19 was 1.82bar higher than diesel. The peak pressure takes place after TDC for safe and efficient operation. If it occurs close to TDC or before that causes severe engine knock thus affects engine durability [16]. It is concluded from the results JME 20% with Compression ratio of 20:1 achieves maximum peak pressure of 3.46 bar higher than diesel and JME20% blend was the optimum fuel blends as far as peak cylinder pressure concerned.

b) *Heat Release Rate*

The variation of heat release rate with crank angle for PME and JME blends at different compression ratio as shown in Fig. 5a-c and Fig. 7a-c. Heat release rate indicates that ignition delay for biodiesel blends was shorter compared with neat diesel. Neat diesel produces maximum heat release of 91.93 kJ/m3deg for CR of 17.5, 87.72 kJ/m3deg for CR of 19, and 79.85 kJ/m3deg for CR 20 respectively. It is observed from figure that maximum heat release rate of biodiesel blends are lower than diesel because of their shorter ignition delay compared with diesel. It is also observed from the obtained values that, JME 20% blend produces minimum heat release rate of 62.53 kJ/m3deg at compression ratio of 20:1 among the biodiesel blends tested.

c) *Ignition Delay*

The variation of ignition delay fordiesel, biodiesel blends at different compression ratio as shown in Fig.8. Ignition delay is one of the important parameters in determining the knocking characteristics of diesel engines. It is a period between start of injection and start of combustion and it depends upon many factors such as compression ratio, the inlet pressure, injection parameters and the properties of the operating fuel. Higher the cetane number (CN), the shorter is the ignition delay, and vice versa [17]. Table. 4 show the ignition delay for biodiesel blends for different compression ratio.It is observed from figure that the ignition delay of methyl esters and its blends is significantly lower than that of diesel and decreases with increase in the percentage of methyl ester in the blend and compression ratio. As the temperature of air in the cylinder is fairly high at the time of injection, esters undergo chemical reactions and polymerization, which result in injection characteristics that are different from those of diesel. A decrease in ignition delay results in smaller amount of fuel accumulation to ignition which results in lower heat release rate during premixed combustion phase.

V. Effect of Biodiesel Blends on Brake Thermal Efficiency

The variation of the brake thermal efficiency with compression ratio for diesel, biodiesel blends at full load were shown in Fig. 9. Brake thermal efficiency (BTE) mainly depends on the operating fuel properties such as density and viscosity. In general, BTE was lower for methyl ester derived biodiesels compared to diesel. To achieve better brake thermal efficiency of biodiesel blends, compression ratio of diesel engine was increased. At full load conditions BTE of diesel, PME10, PME20, PME30, JME10, JME20, JME30 are 28.1%, 26%, 27%, 30%, 30.3%, 33.5%, 35.6% respectively. It is observed from the figure that BTE gets increased proportionally with engine loads. JME30% blend produces 7.5% higher brake thermal efficiency than diesel. Increase in compression ratio of engine enhance the complete combustion of fuel in the combustion chamber with the presence of oxygen and hence better thermal efficiency.

VI. Conclusion

The experiments reveals that biodiesel from unrefined Jatropha and Pongamia seed oil is quite suitable as an alternative to diesel. Following results were obtained from the bio fuel operated single cylinder diesel engine operation.

- The ignition delay was shorter for PME blends (10%, 20%, and 30%) varying between 12.6 to 14.2 CA for different compression ratios 17.5:1, 19:1, 20:1 compared with diesel.
- The ignition delay was shorter for JME blends (10%, 20%, and 30%) varying between 12.9 to 14.28 CA for different compression ratios 17.5:1, 19:1, 20:1compared with diesel.

Global Journal of Researches in Engineering (A) Volume XIV Issue VII Version I Year 2014

© 2014 Global Journals Inc. (US)

- It is concluded that biodiesel (JME and PME) blendsreleases maximum peak pressure compared with diesel and peak pressure increases while increasing the compression ratio.
- It is also concluded that Heat release rate is less for biodiesel fuel blends compared with diesel fuel. Among the tested blends JME 20% blend produce minimum heat release rate of 62.48 kJ/m3deg at 20:1 compression ratio.
- Brake thermal efficiency increases with increase in compression ratio for biodiesel blends.

VII. Acknowledgement

Sincere thanks and gratitudeto the Principal & Management of SVCE for granting permission to use the facilities in the college for this research work.

Our Sincere thanks to Mr. R. Raj Jawahar from Dynamechz Research Labs for providing technical supports.

References Références Referencias

1. Gerhard Knothe, Biodiesel and renewable diesel: A comparison. Progress in Energy and Combustion Science xxx (2009) 1–10.
2. C. Carraretto, A. Macor, A. Mirandol, A. Stoppato, S. Tonon, Biodiesel as alternative fuel: Experimental analysis and energetic evaluations. Energy 29 (2004) 2195–2211
3. R. Altin, S. Cetinkaya, H.S. Yucesu, Potential of using vegetable oil fuels as fuel for diesel engines, Energy Conversion Manage. 42 (2001) 529–538.
4. Avinash Kumar Agarwal, Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science 33 (2007) 233–271.
5. Fangrui Ma, Milford A. Hanna, Biodiesel production: a review. Bio resource Technology 70 (1999) 1-15.
6. Md. Hasan Alia, Mohammad Mashud, Md. Rowsonozzaman Rubel, Rakibul Hossain Ahmad, Biodiesel from Neem oil as an alternative fuel for Diesel engine. Procedia Engineering 56 (2013) 625 – 630.
7. Shailendra Sinha, Avinash Kumar Agarwal, Sanjeev Garg, Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization. Energy Conversion and Management, Volume 49, Issue 5, May 2008, Pages 1248–1257.
8. Qi, D.H, Chen, H., Mattews, R.D, Bian., Y. Z., Ren, X.CH., 2010. Performance and Combustion characteristics of biodiesel-diesel-methanol blend fuelled engine, Applied Energy 87, p. 1679.
9. Luis Felipe Ramirez-Verduzco, Javier Esteban Rodriguez-Rodriguez, Alicia del Rayo Jaramillo-Jacob, Predicting cetane number, kinematic viscosity, density and higher heating value of biodiesel from its fatty acid methyl ester composition. Fuel Volume 91, Issue 1, January 2012, 102–111.
10. K. Nantha Gopal, Arindam Pal, Sumit Sharma, Charan Samanchi, K. Sathyanarayanan, T. Elango, Investigation of emissions and combustion characteristics of a CI engine fueled with waste cooking oil methyl ester and diesel blends. Alexandria Engineering Journal (2014) 53, 281–287.
11. Zhu L, Cheung CS, Zhang WG, Huang Z. Combustion, performance and emission characteristics of a DI diesel engine fueled with ethanol–biodiesel blends. Fuel 2011; 90:1743–1750.
12. Mohammed EL-Kasaby, Medhat A. Nemit-allah, Experimental investigations of ignition delay period and performance of a diesel engine operated with Jatropha oil biodiesel. Alexandria Engineering Journal (2013) 52, 141–149.
13. V. Palvannan, K. Balagurunathan, Technical Sustainability of Cashew Nut Shell Liquid as a Renewable Fuel in Compression Ignition Engine. European Journal of Scientific Research Vol.76 No.4 (2012), pp.614-627.
14. Effect of injection timing on performance, combustion and emission characteristics of a diesel engine using mahua oil methyl ester as fuel. journal of scientific & Industrial research vol. 71, January 2013, pp.69-74.
15. Meher, L.C. Sagar, D.V. Naik, Technical aspect of biodiesel production by Transesterification- a review, Renewable and Sustainable Energy Review 10, 2006. p. 248.
16. P.K. Sahoo, L.M. Das, Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine. Fuel 88 (2009) 994-999.
17. John B Heywood. 1988. Internal Combustion Engine Fundamentals. McGraw Hill Book Company.

© 2014 Global Journals Inc. (US)

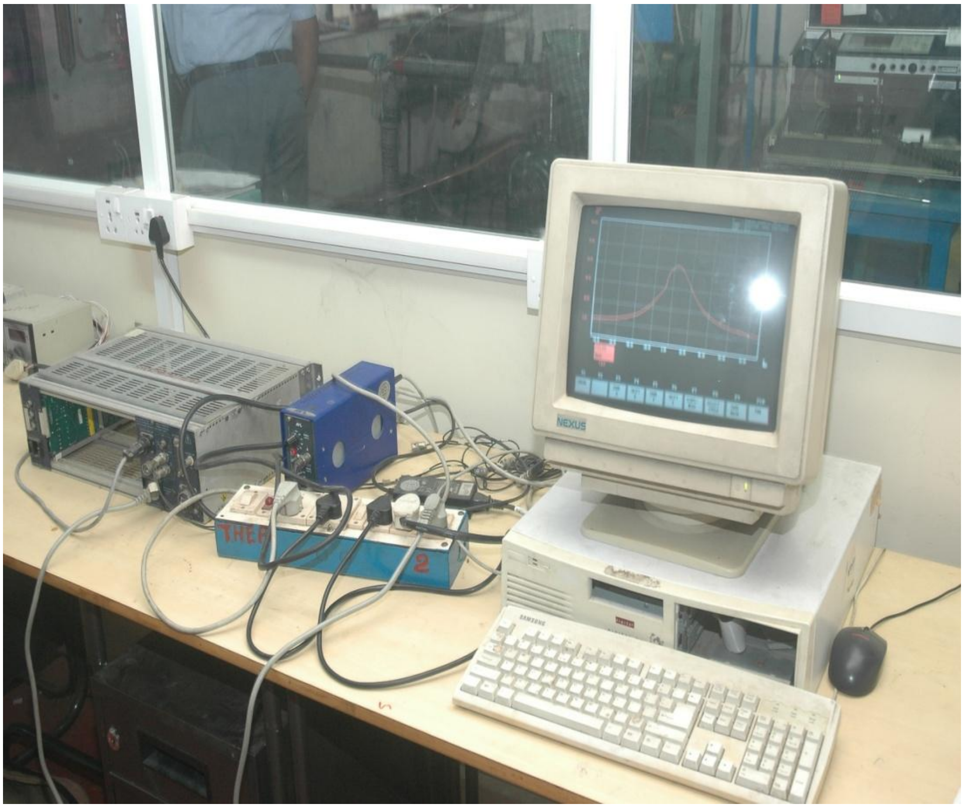
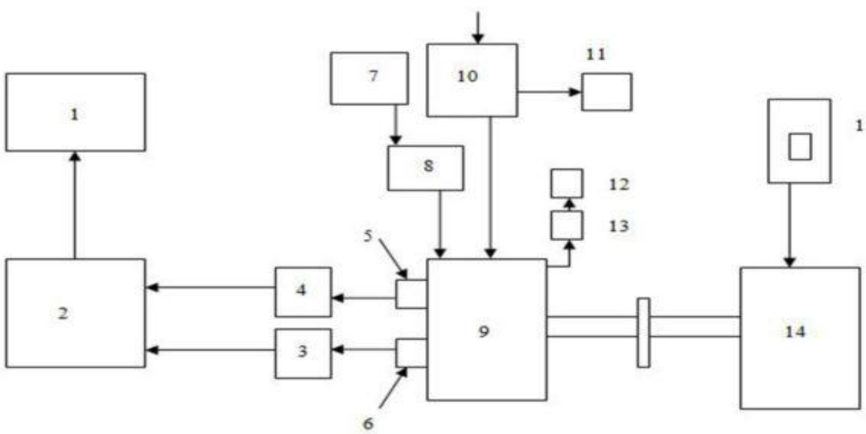


Figure 1 : AVL Data acquisition system



1. Computer	9. Diesel engine
2. A/D card	10. Air box
3. TDC amplifier circuit	11. U-tube manometer
4. Charge amplifier	12. Exhaust gas analyzer
5. Pressure transducer	13. AVL smoke meter
6. TDC position sensor	14. Electric dynamometer
7. Fuel tank	15. Dynamo meter control
8. Fuel flow meter	

Figure 2 : Layout of diesel engine setup

© 2014 Global Journals Inc. (US)

Figure 3 : Test engine setup

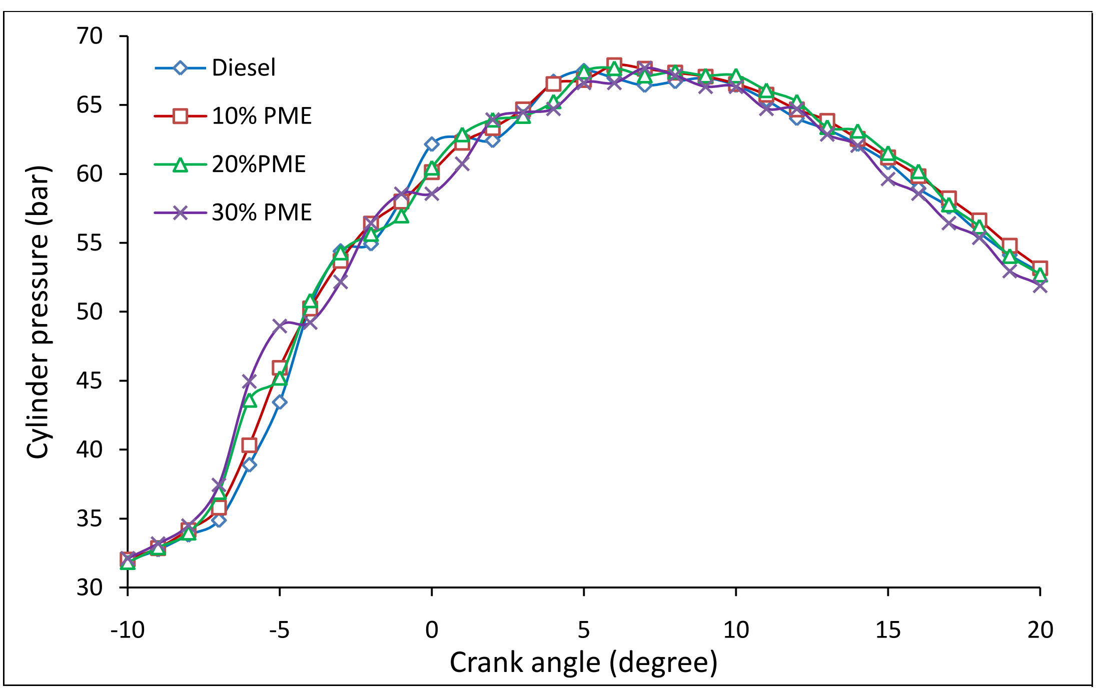


Figure 4a: Crank angle vs. cylinder pressure for compression ratio of 17.5

© 2014 Global Journals Inc. (US)

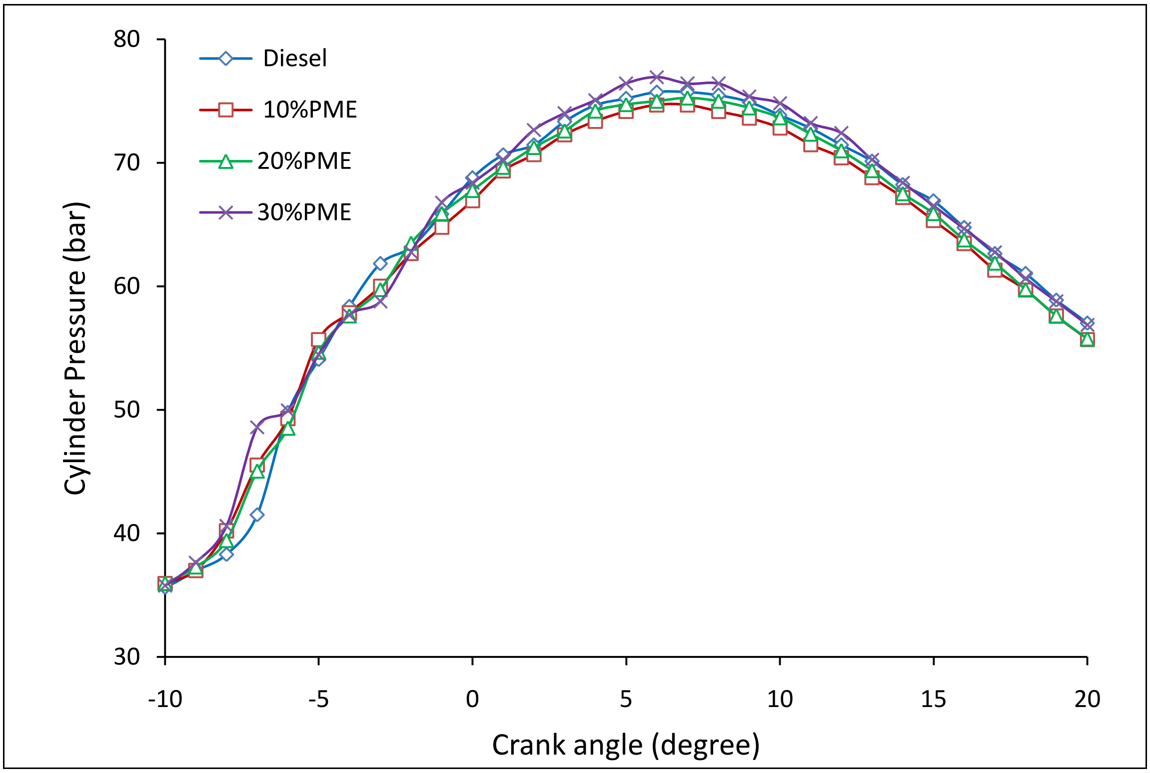


Figure 4b : Crank angle vs. cylinder pressure for compression ratio of 19

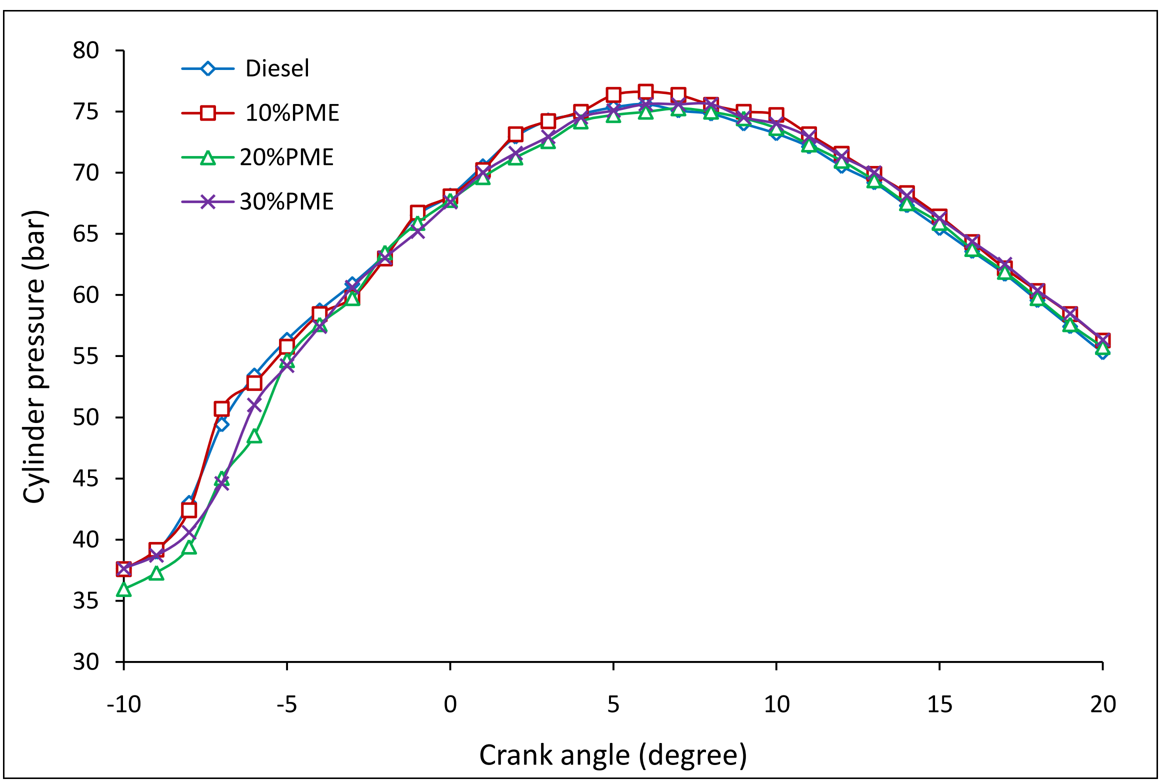


Figure 4c : Crank angle vs. cylinder pressure for compression ratio of 20

© 2014 Global Journals Inc. (US)

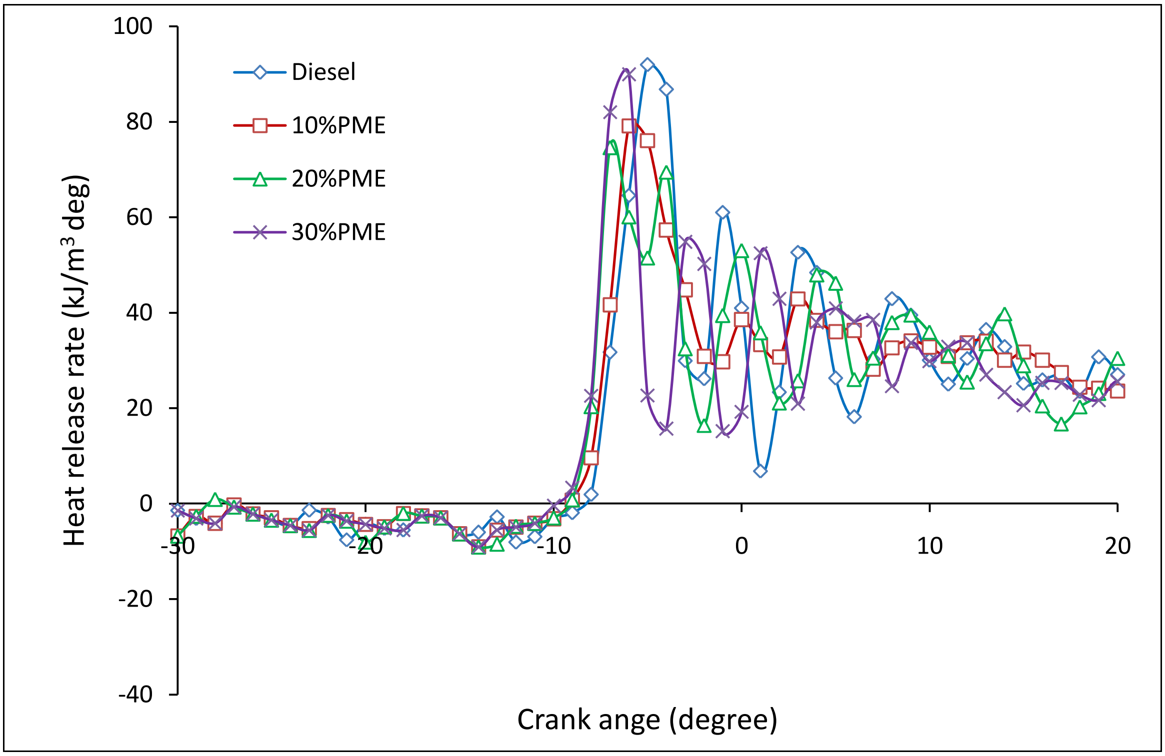


Figure 5a : Crank angle vs. heat release rate for compression ratio of 17.5

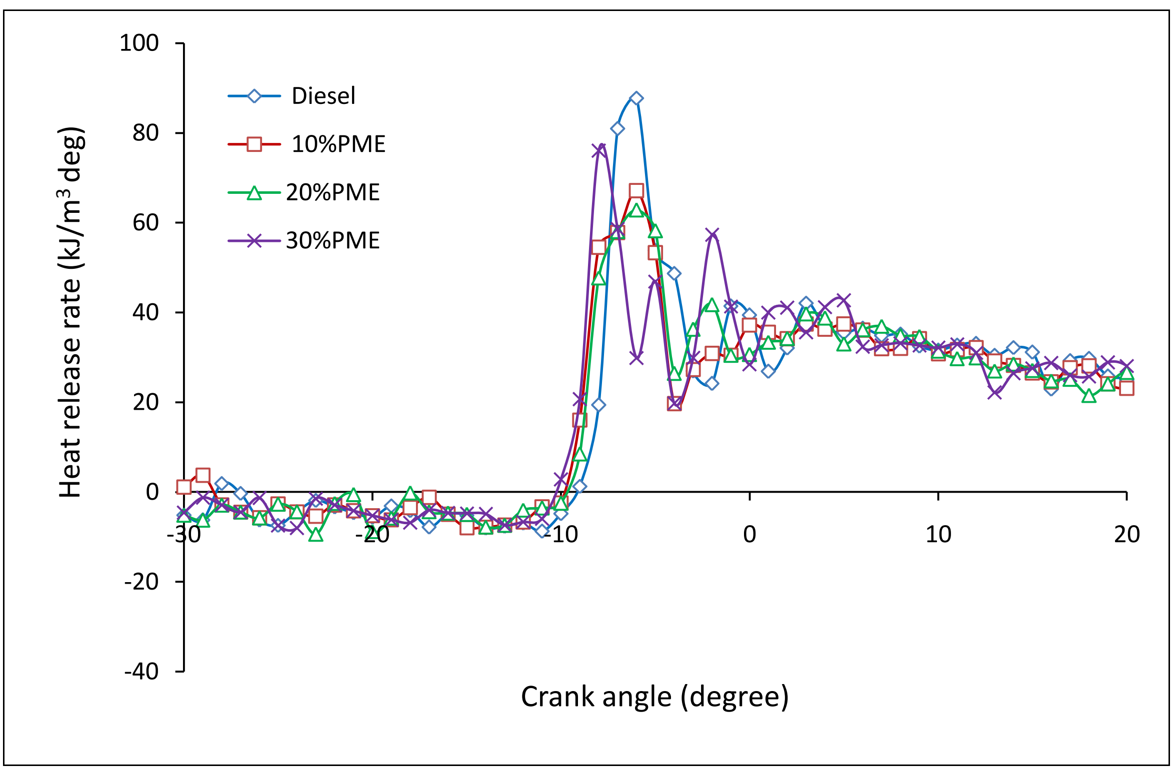


Figure 5b : Crank angle vs. heat release rate for compression ratio of 19

© 2014 Global Journals Inc. (US)

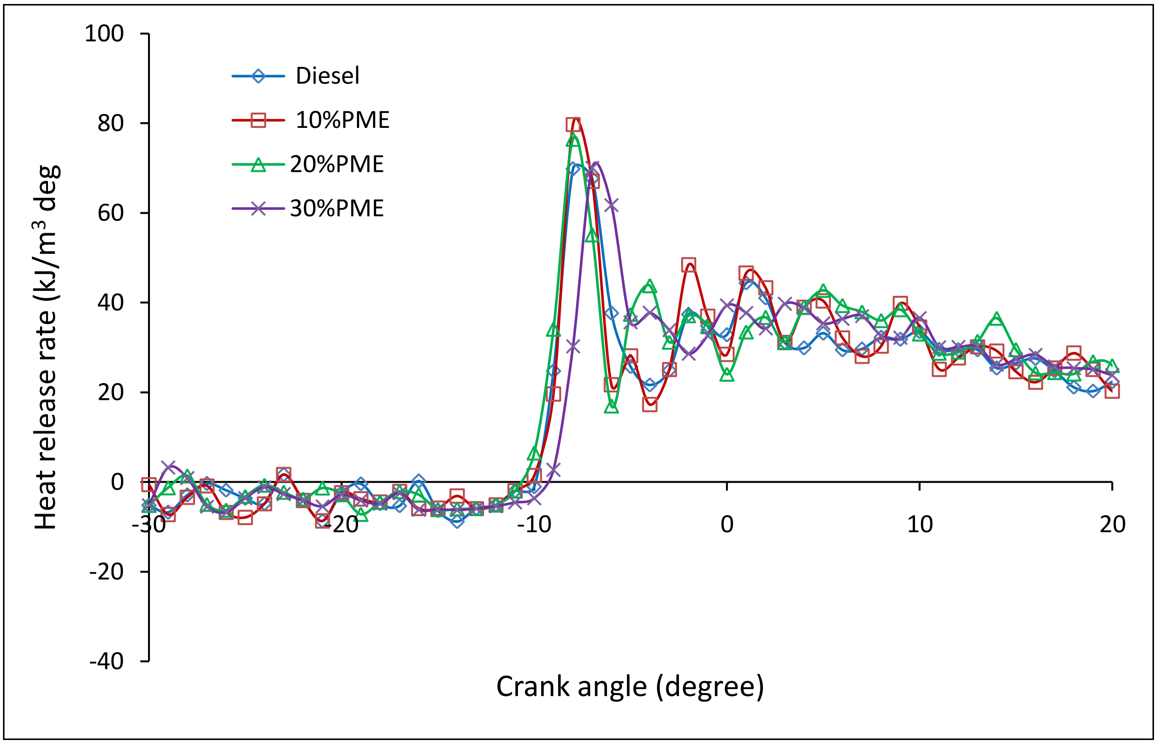


Figure 5c : Crank angle vs. heat release rate for compression ratio of 20

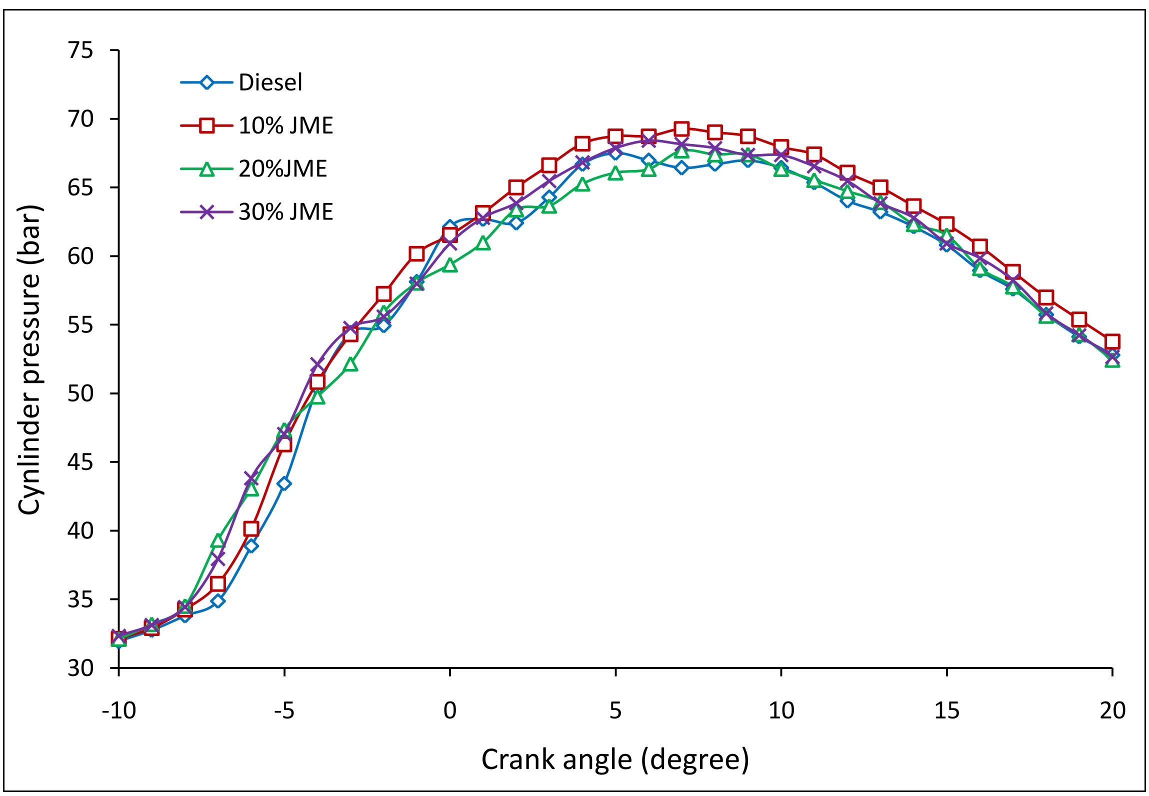


Figure 6a : Crank angle vs. cylinder pressure for compression ratio of 17.5

© 2014 Global Journals Inc. (US)

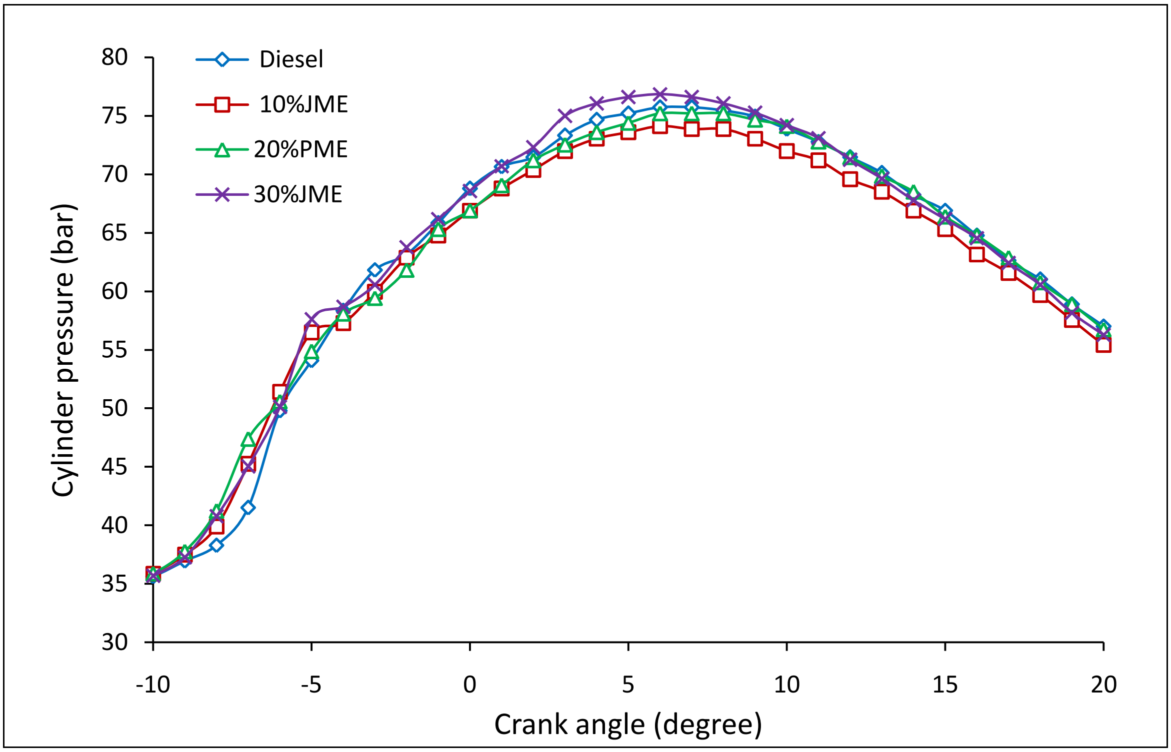


Figure 6b : Crank angle vs. cylinder pressure for compression ratio of 19

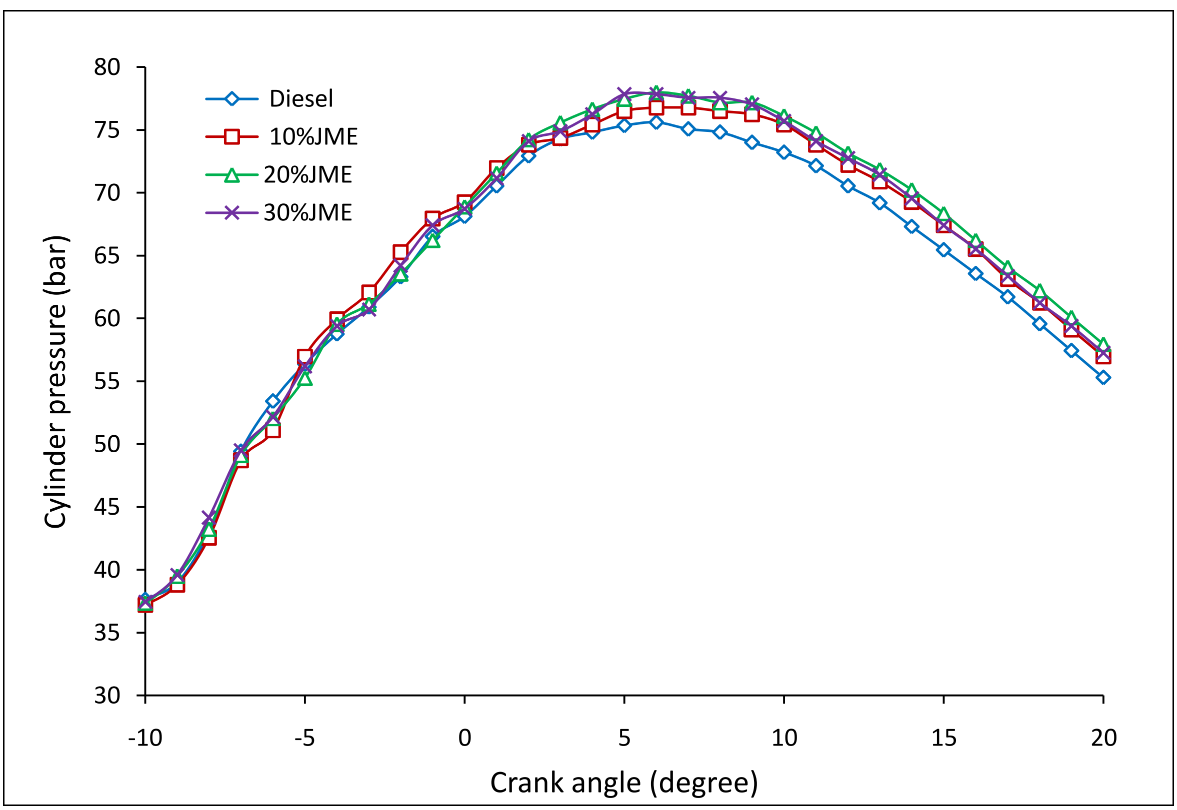


Figure 6c : Crank angle vs. cylinder pressure for compression ratio of 20

© 2014 Global Journals Inc. (US)

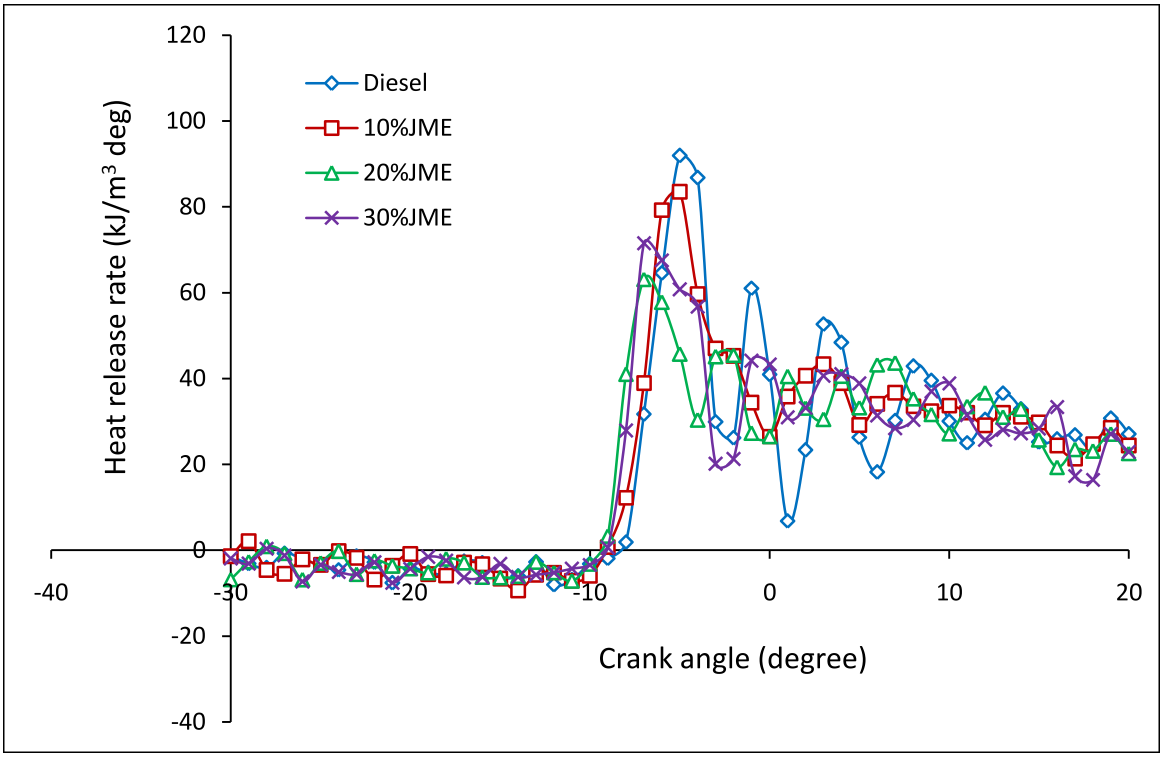


Figure 7a : Crank angle vs. heat release rate for compression ratio of 17.5

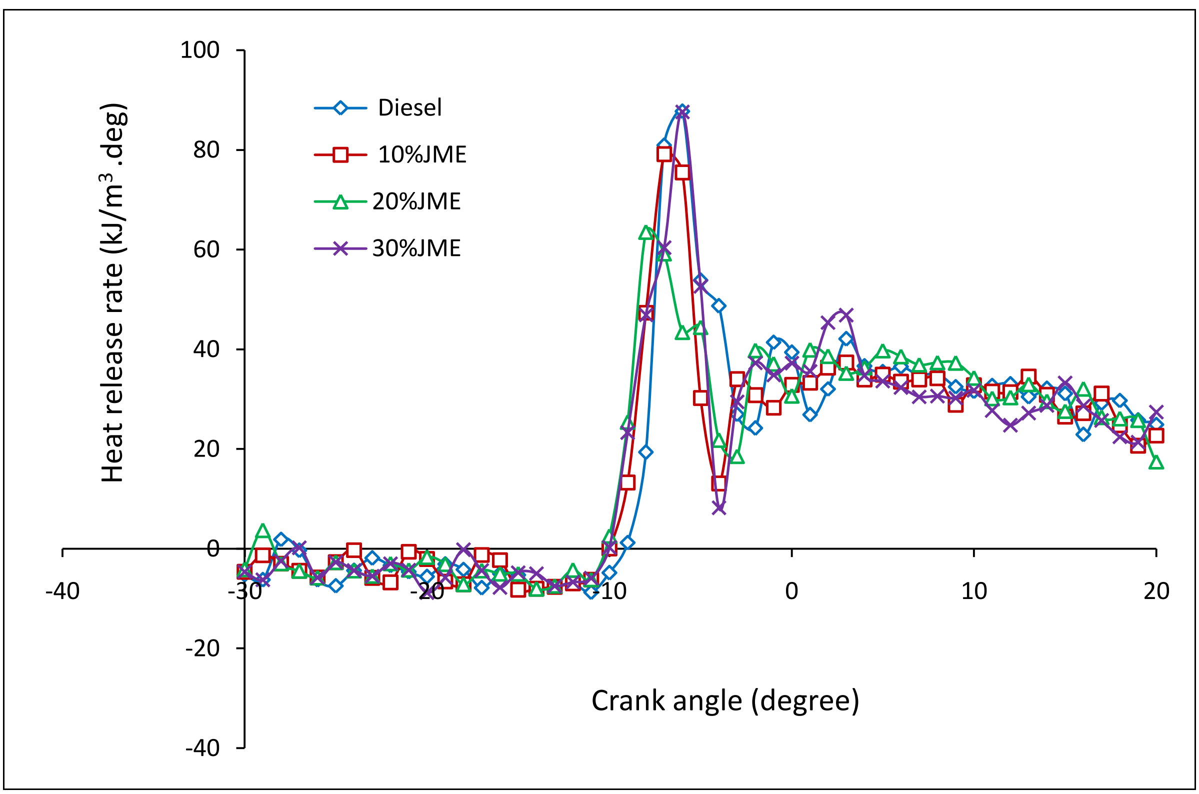


Figure 7b : Crank angle vs. heat release rate for compression ratio of 19

© 2014 Global Journals Inc. (US)

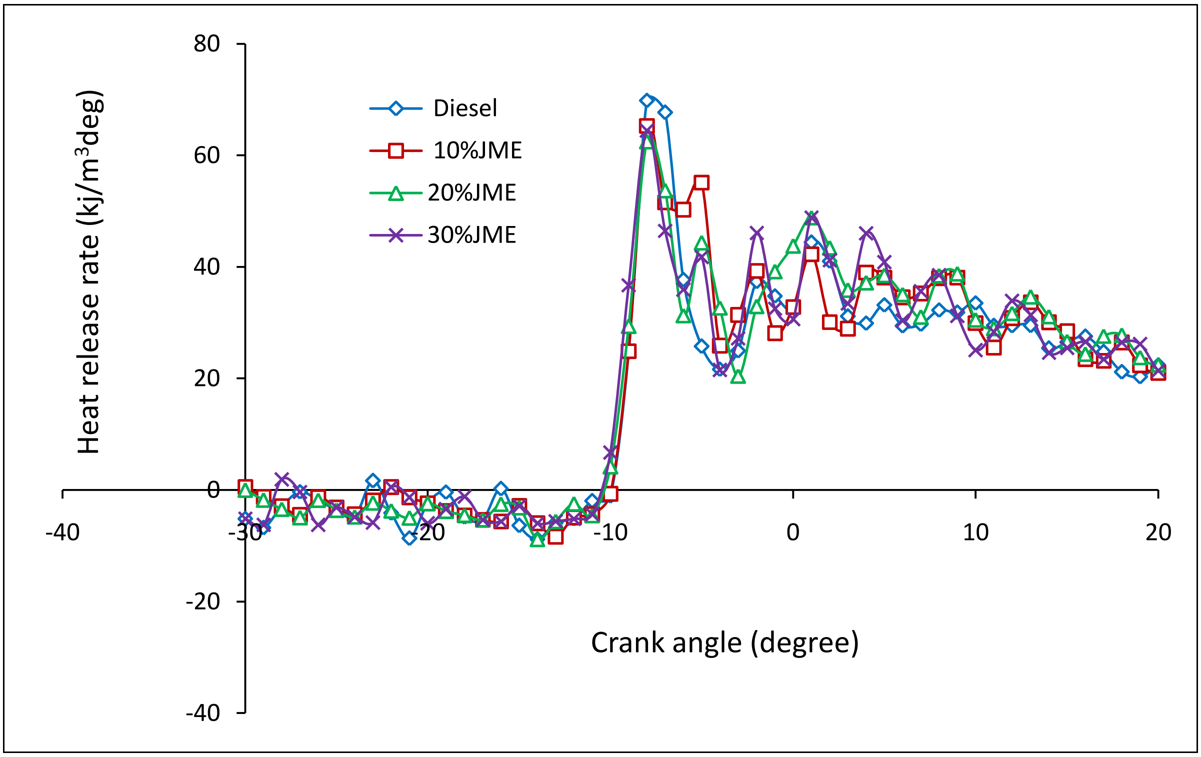


Figure 7c : Crank angle vs. heat release rate for compression ratio of 20

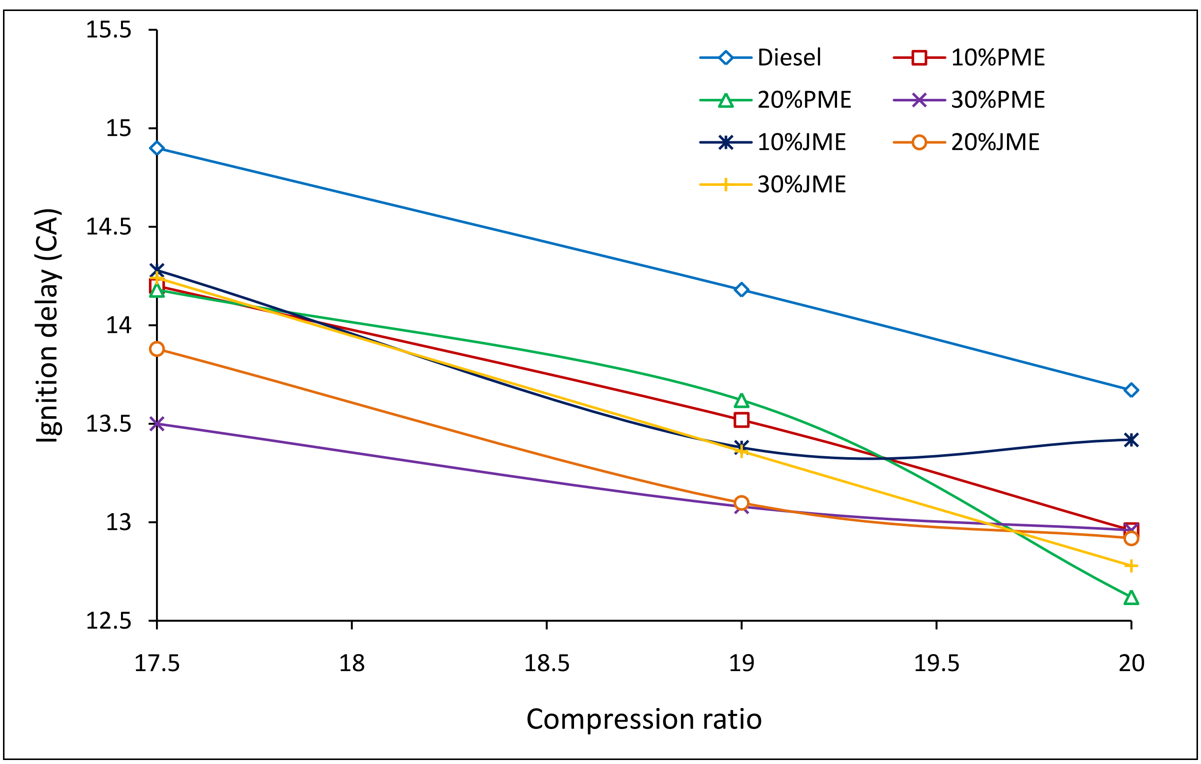


Figure 8 : Compression ratio vs. Ignition delay

© 2014 Global Journals Inc. (US)

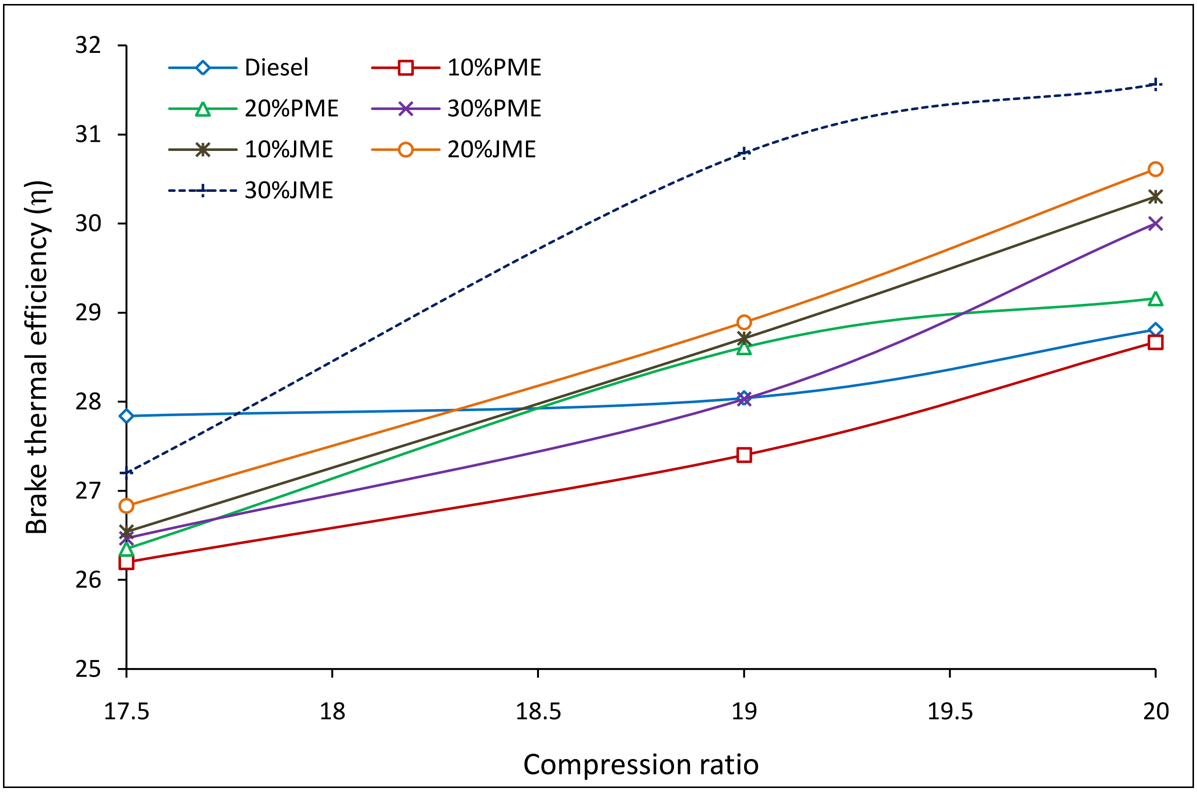


Figure 9 : Brake thermal efficiency vs. compression ratio at full loads

Table 1 : Diesel and biodiesel blends

Fuel blend	Density (kg/m^3)	Calorific value (kJ/kg)	Kinematic viscosity at 40^{0}C (cSt)	Flash point (^{0}C)	Cetane number
DIESEL	840	43000	3.90	50	48
PME10	868	37956	5.17	162	52.70
PME20	870	38450	5.43	169	53.01
PME30	874	39423	5.62	171	53.4
JME10	882	35412	5.21	160	46.17
JME20	897	36010	5.64	163	46.48
JME30	891	37675	5.97	166	46.80
IS for biodiesel (IS15607:2005)	860-900	-	2.5-6.0	120 min	46 min

Table 2 : Diesel engine Specifications Particulars

Particulars	Specifications
Engine model	Kirloskar TAF-1
Fuel injection type	Direct injection
No of cylinder	1
Bore & Stroke	87.5mm & 110mm
Compression ratio	17.5:1
Cooling system	Air –cooled

© 2014 Global Journals Inc. (US)

Fuel injection time	23.4 degree bTDC
Injection pressure	200 bar
Loading type	Eddy current dynamometer
Maximum power	4.4 kW@1500rpm
Maximum torque	28 N-m@1500rpm
IVO	4.5 degree bTDC
IVC	35.5 degree aBDC
EVO	35.5 degree bBDC
EVC	4.5 degree aTDC

Table 3 : Instruments used for engine test

Instrument	Measurement	Range	Accuracy	Percentage of uncertainties
AVL GH14D Pressure Transducer	Cylinder pressure	0-110 bar	±1 bar	0.20
AVL 365C angle encoder	Crank angle	--	±1	1
K type Thermocouple	EGT	0-1500°C	±1°C	0.4
Burette	Fuel consumption	1-30 cc	±0.1cc	0.15
U-tube Manometer	Inlet flow rate	-	±1 mm	0.5
Stopwatch	Time	-	±0.2sec	0.2
Load cell	Load	250-600 W	±1 W	0.21

Table 4 : Ignition delay, Peak pressure, heat release rate for diesel and biodiesel blends

Fuel	Start of combustion (^{0}) bTDC			Ignition delay			Peak pressure (bar)			Heat release rate (kJ/m^{3}deg)		
	17.5	19	20	17.5	19	20	17.5	19	20	17.5	19	20
Diesel	8.5	9.3	10	14.9	14.1	13.4	67.49	75.12	75.61	91.93	87.72	79.85
PME 10	9.2	9.9	10.5	14.2	13.5	12.9	67.88	75.68	76.62	79.17	67.12	78.79
PME 20	9.22	9.8	10.8	14.18	13.6	12.6	67.67	75.25	75.33	74.58	62.83	76.47
PME 30	9.9	10.4	9.5	13.5	13.0	13.9	67.67	76.94	75.61	89.92	76.07	70.07
JME 10	9.12	10.1	10	14.28	13.3	13.4	69.28	77.12	76.76	83.50	79.11	65.32
JME 20	9.52	10.3	10.5	13.88	13.1	12.9	70.67	77.98	79.18	63.10	63.53	62.48
JME 30	9.16	9.8	10.5	14.24	13.6	12.9	69.42	78.85	77.83	71.47	84.61	64.42

© 2014 Global Journals Inc. (US)