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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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◆

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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EFFECT OF PREMIX AND EXHAUST GAS RECIRCULATION ON THE EMISSION CHARACTERISTICS OF BIODIESEL FUELED ENGINE

Abstract. In the present work, an attempt has been made to reduce NO_x and PM using diesel premixed compression ignition engine. Diesel fuel with 20% Jatropha oil methyl ester (JOME) blends as the main fuel injected into the cylinder and diesel as the premixed fuel injected into the intake manifold. Diesel fuel was injected into the intake manifold to form homogeneous pre-mixture and the premixture is burnt in the cylinder with the balance quantity of fuel directly injected into the cylinder. Experiments were conducted with 10%, 20%, and 30% EGR for the premixed ratio 25% and results are compared with conventional diesel fuel operation. It was observed that the diesel injection and JOME blend in the main injection results in better mixture preparation and lower emissions. Significant reduction in NO_x and PM were achieved with the mode at Rp 25% and EGR 20% in the JOME-Diesel mode of operation. The percentage increases in peak heat release rate were 40.6%, 30.6% and 22.8 % compared to CIDI mode. The premixed ratio of 0.25 with 20% EGR was observed to be optimum in D-20J comparing the performance, combustion and emission characteristics.

Keywords: diesel premix; Charge compression ignition; Jatropha methyl ester; Exhaust gas recirculation.

Introduction. The need for the energy is increasing day by day with the growth of population and requirement of modern energy consuming equipment for comfort living. The invention of internal combustion engine and developments in engine technology resulted in exploitation of the petroleum based reserves which is depleting at a rapid rate [1]. Diesel engines have been used for better thermal efficiency, however diesel engine have the disadvantage of producing smoke, smoke density and NO_x and it is difficult to simultaneously to reduces NO_x, and smoke density diesel engine [2-9]. Reducing these emissions and increasing the fuel economy of IC engines are the primary concern for all developing nations [10]. There has been a world-wide interest in the search for alternatives to petroleum derived fuels due to their depletion and concern for the environment. Biodiesel derived from edible, non-edible oils and animal fats can be used in diesel engines with little or no modifications [11-14].

Jatropha oil methyl esters are well-proven alternatives fuel to petroleum diesel [15]. Tumbal in 2016 conducted studies in a diesel engine’s performance and results have been compared with those of neat diesel fuel and conclude that by advancing the injection timing from the base diesel and increasing the injector opening pressure, increase the brake thermal efficiency and reduce HC and smoke emission significantly [16]. Jatropha cultivation requires sufficient area as well as clean and good seed to generate sufficient oil [17-19]. Fast degradation and energy crisis of the environment, researchers and government must find appropriate plan to overcome these challenges and impose the biofuel policy to use the jatropha biodiesel as a replacement for diesel fuel [20]. Waste cooking oil can be used to reduce petroleum diesel consumption and lower the carbon monoxide, unburned hydrocarbon, and smoke opacity in the same time reduce the brake thermal efficiency. Waste cooking oil biodiesel blends showed similar trends when to that of conventional diesel [21]. Even though biodiesel offers the reduction in smoke, UBHC and CO emission due to the molecular oxygen present in it, NO_x emissions are higher which can be reduced by using exhaust gas recirculation [22, 23]. Exhaust gas recirculation (EGR) is an effective way to reduce NOx emissions in diesel engine along with soybean oil methyl ester and EGR replaces the incoming air in the manifold. The experimental results reveal that soybean oil methyl ester with EGR can be used to reduce NOx and smoke intensity simultaneously [24].

Homogeneous Charge Compression Ignition (HCCI) engines have lower theses emissions due to the homogeneous fuel air mixture, in which the composition and the thermodynamic conditions are uniform throughout the reaction phase [25-28]. The low emissions of PM and NOx in HCCI engines are a result of the and fuel mixture evaporated prior to the start of the reactions. The challenges over the operation of HCCI engines are the controlling the auto-ignition of the air fuel mixture, operating range, charge preparation and cold start [29, 30]. The change in HCCI engine may be made dilute by being very lean, by stratification, by using exhaust gas recirculation (EGR), or combination of these methods. Since HCCI engine operates on lean mixtures, the peak temperatures always lower and low peak temperatures prevent the formation of NO_x [31].

Diesel Premixed Compression Ignition Engine (DPCIE). It is proposed to study the effect of diesel premixed compression ignition engine (DPCIE) mode a type of HCCI combustion mode in diesel engines [32-34]. In this method, two fuels are used. One fuel is injected into the intake air, upstream of the intake valve to obtain a premixed charge. Remaining fuel is injected into the combustion chamber through conventional injection system. The DPCIE technique reduces NOx and PM using partially premixed charge compression ignition (DPCIE) combustion [33-35]. It is observed that not much work has been done on the usage of biodiesel in DPCIE combustion mode. Hence an attempt was made to study the effect of Jatropha methyl ester biodiesel as main fuel and diesel as premixed fuel. Therefore, in DPCIE combustion takes place with a highly diluted mixture to maintain the temperature and pressure low in the cylinder and is normally restricted to low loads. In the present experimental work, the performance, emission and combustion characteristics have been studied using jatropha oil methyl esters in CIDI and HCCI modes with the following objectives:

– To find the optimum EGR percentages for the better tradeoff of soot and NO_x emissions for JOME.

– To study the effect of DPCIE combustion mode with diesel and biodiesel blends.

The conclusions arrived on various experiments conducted using DPCIE mode of combustion with diesel as premixed fuel with the premixed ratio of 0.25 and 20% JOME as main fuel with 10%, 20% and 30% EGR. The performance, emission characteristics and combustion parameters (in-cylinder pressure, ignition delay and heat release rate) are presented.

Experimental Setup. The tests are conducted on a single cylinder, four stroke, naturally aspirated, air-cooled diesel engine coupled with an electrical swinging field dynamometer. The detailed technical specifications of the engine are given in table 1. Figure 1 shows the schematic diagram of the experimental set-up.

Experimental Procedure. The engine was started with diesel and allowed to warm up till steady state conditions were achieved. Engine Speed, fuel consumption rate, exhaust emissions (HC, CO, and NO_x), smoke intensity, pressure-crank angle diagram and exhaust gas temperature were measured at various loads. The experiment was repeated at various loads with 20% JOME blends with diesel. The experiments were conducted on a CIDI engine maintained at 25%, 50%, 75% and 100% of brake power output at the speed of 1500 rpm with modified inlet manifold to operate the engine in DPCIE combustion mode. The experiment was repeated with premixed ratios of 0.25 at various power outputs. The notations are used in DPCIE mode:

D-20J mode - Diesel (manifold injection)-20% JOME and 80% Diesel blends (main injection).

Rp - The ratio of the energy of premixed fuel Qp to the total energy Q_t.

$$Rp = Q_p/Q_t = (m_p{*}CV_p)/m_p{*}CV_p + m_d{*}CV_d\,. \tag{1}$$

Where m is the mass of fuel and CV is the lower calorific value and subscripts p and d refer to premixed and directly injected fuel, respectively.

Table 1 – Test Engine Specifications

Make and Model	Kirloskar, TAF1 make
General Details	Four stroke, compression ignition, constant speed, vertical, air cooled, direct injection
Number of Cylinders	one
Bore	87.5 mm
Stroke	110 mm
Swept Volume	661 cc
Clearance Volume	36.87 cc
Compression Ratio	17.5:1
Rated Output	4.4 kW at 1500 rpm
Rated Speed	1500 rpm
Type of Injection Pump	Mechanical
Nozzle Holes	3 holes
Spray Hole Diameter	0.25 mm
Nozzle Opening Pressure	200 bar
Cone Angle	110°
Type of Injector	Mechanical
Needle Lift	0.25 mm
Fuel Injection Timing	23 ^{o}CA bTDC
Fuel Injection Duration	20 - 30 ^{o}CA
Type of Combustion Chamber	Hemispherical Open Combustion Chamber without offset with 52 mm diameter on top. Bowl volume is approximately 40 cm^3
Valve Timing	
Intake Valve Opening	4.5°CA bTDC
Intake Valve Closing	35.5°CA aBDC
Exhaust Valve Opening	35.5°CA bBDC
Exhaust Valve Closing	4.5°CA aTDC

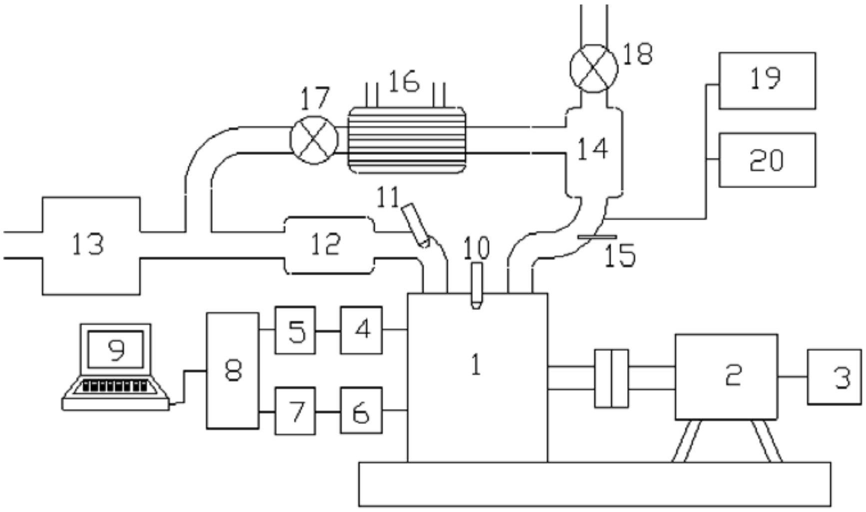

Figure 1 – Experimental Setup:
1 – Diesel Engine; 2 – Electrical Dynamometer; 3 – Dynamometer Controls; 4 – Pressure pickup; 5 – Charge amplifier; 6 – TDC position sensor; 7 – TDC amplifier circuit; 8 – A/D Card; 9 – Personal computer; 10 – Main Injector; 11 – Premixed fuel injector; 12 – Mixing chamber; 13 – Air flow measurement; 14 – Settling chamber; 15 – Thermocouple; 16 – EGR Cooler; 17 – EGR Valve; 18 – Back pressure control valve; 19 – Exhaust gas analyzer; 20 – AVL smoke meter

Error Analysis. To decide the accuracy of the findings the errors and uncertainties in the experiment are important so, instruments are selected carefully and the percentage uncertainties of various parameters are given in table 2.

Table 2 – List of instruments and their range, accuracy, and uncertainties

Sl. No.	Instruments	Range	Accuracy	Percentage uncertainties
1	Gas analyzer			
	CO	0 – 15.00%	±0.06%	±5%
	Hydro carbon (HC)	0 – 20000 ppm n-hexane	±0.12ppm	±5%
	NOx	0 – 2000 rpm	±5 ppm	±5%
2	Smoke meter	0 – 32000 mg/m^3	± 0.01 mg/m^3	±5%
3	K type Thermocouple	0–1000	±1	±0.15
4	Speed measuring unit	0–9,999 rpm	5 ± 10 rpm	±0.1
5	Pressure pickup	0–250 bar	± 0.1	± 0.1
6	Crank Angle encoder	0-360°	±1°	± 0.2

Results and Discussion. In the present work, reduction of NO$_x$ and PM with Partially Premixed Charge Compression Ignition (DPCIE) combustion was investigated. Diesel was used as a premixed fuel with the premixed ratio of 0.25 along with 20% jatropha oil methyl ester (JOME) blend as main fuel with 10%, 20% and 30% EGR. Diesel fuel was injection into the intake manifold using a solenoid operated injector controlled by Electronic Control Unit (ECU) to form premixed charge. The pre-mixed charge was burnt in the cylinder along with the fuel directly injected into the cylinder by a conventional injection system. To control the start of combustion and NOx emissions, EGR was adopted and the exhaust gas was varied from 10% to 30% in steps of 10%.

Specific Energy Consumption and Brake Thermal Efficiency. Figure 2 and 3 shows the variation of SEC and brake thermal efficiency with brake power for CIDI mode and D-20J mode with the premixed ratio of 0.25 without EGR and with 10%, 20% and 30% EGR. As the percentage of EGR increases, the SEC increases and brake thermal efficiency decreases compared to CIDI mode. When EGR is introduced the fuel air mixture is diluted and the decrease in the availability of oxygen retards the combustion. The heat release in combustion reactions is decreased and the quantity of unburned fuel is relatively large. As EGR increases, the brake thermal efficiency decreases.

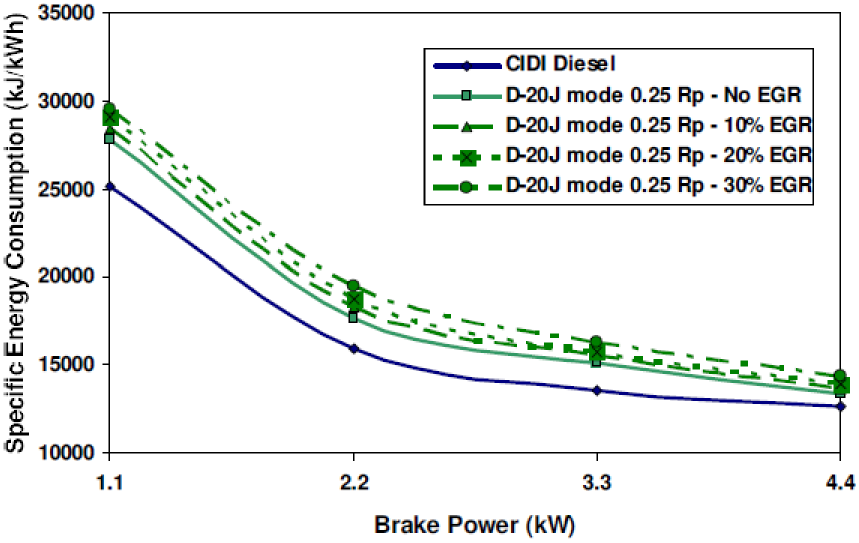

Figure 2 – Variation of Specific Energy Consumption with Brake Power

The SEC varies from 13,420 to 14,417 kJ/kWh in D-20J for the premixed ratio of 0.25 without EGR and with 10%, 20% and 30% EGR compared to 12,661 kJ/kWh in CIDI mode at rated power output. The brake thermal efficiency varies from 26.8 % to 25.0% in the D-20J mode for above mode compared to 28.4% in CIDI mode.

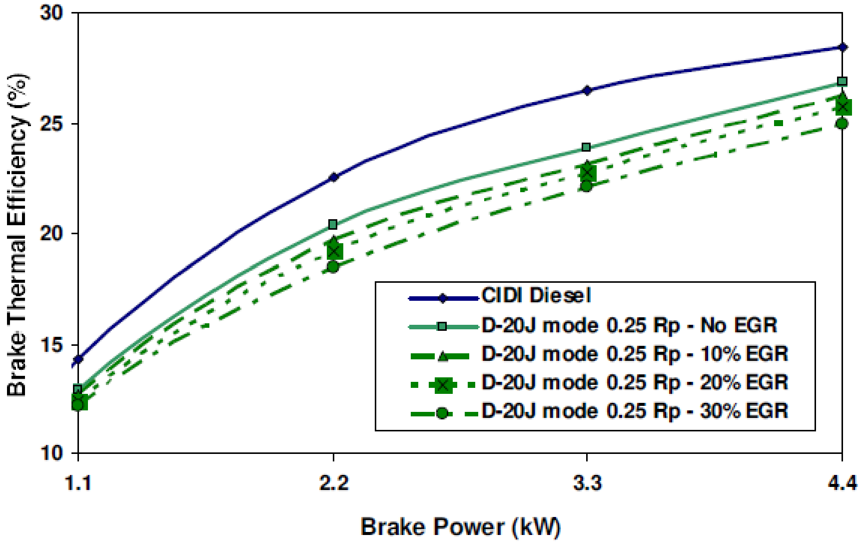

Figure 3 – Variation of Brake Thermal Efficiency with Brake Power

Exhaust Gas Temperature. The variation of exhaust gas temperature with brake power for D-20J with premixed ration of 0.25 with 10%, 20% and 30% EGR and without EGR compared with CIDI mode is shown in figure 4. The combustion starts earlier resulting in higher in-cylinder temperature and pressure.

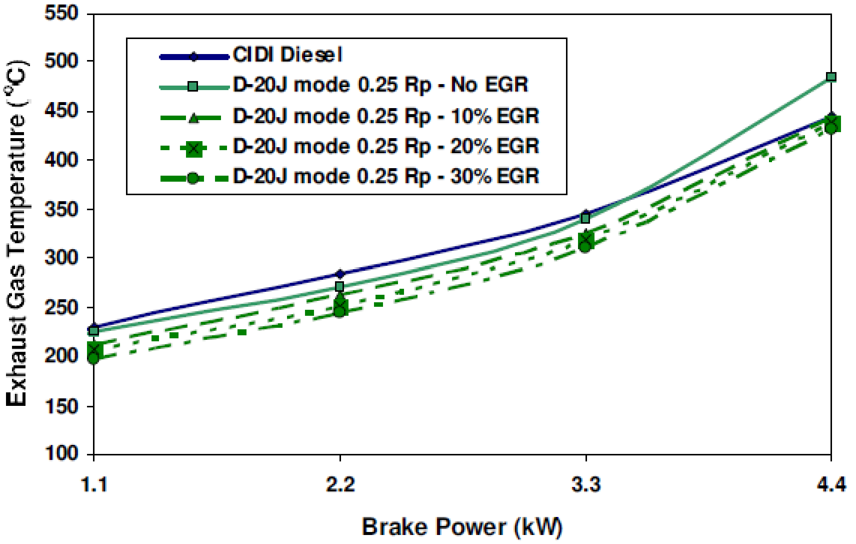

Figure 4 – Variation of Exhaust Gas Temperature with Brake Power

These results in higher exhaust gas temperature at rated power output with the premixed ratio of 0.25 without EGR compared to base line diesel mode. With EGR, the specific heat capacities of re-circulated H_2O and CO_2 constituents increase resulting in lower peak combustion temperature. The effect is more pronounced at higher EGR percentages. At rated power output, the exhaust gas temperature varies from 444ºC to 431ºC with 10%, 20% and 30% EGR for the premixed ratio of 0.25 compared to 485ºC without EGR in D-20J mode.

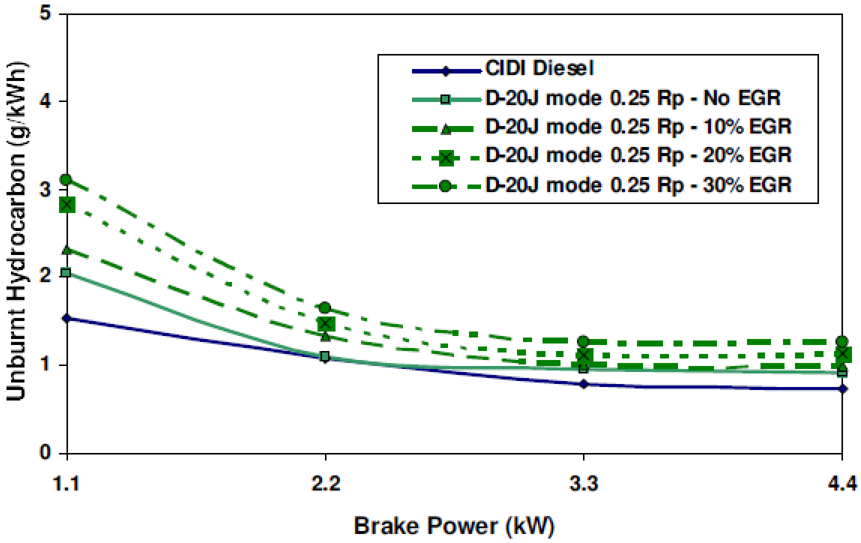

Figure 5 – Variation of Unburnt Hydrocarbon with Brake Power

Unburnt Hydrocarbon and Carbonmonoxide Emissions. Figure 5 shows the variation of UBHC with brake power for CIDI mode, for DPCIE mode with D-20J 10, 20 and 30% EGR and without EGR. The variation of CO emissions is shown in Figure 6 for the same operating conditions. Reduction of oxygen with EGR reduces the combustion reaction rate and the temperature inside the cylinder. The burned gas temperature is low which results in increased emissions of UBHC and CO compared to CIDI mode. The peak temperatures are also relatively low to complete the oxidation of CO to CO_2.

Due to lower inlet temperatures, premixed diesel fuel and in-cylinder injection of methyl ester blends are not completely evaporated which also leads to higher UBHC and CO. The effects of crevice volume and flame quenching may also be responsible for high UBHC and CO emissions. The UBHC emissions vary from 0.9 to 1.2 g/kWh in D-20J for premixed ratio of 0.25 without EGR and with 10%, 20% and 30% EGR compared to 0.7 g/kWh in CIDI mode at rated power output and the CO emissions vary from 17.6 to 30.9 g/kWh in D-20J mode compared to 16.7 g/kWh in CIDI mode.

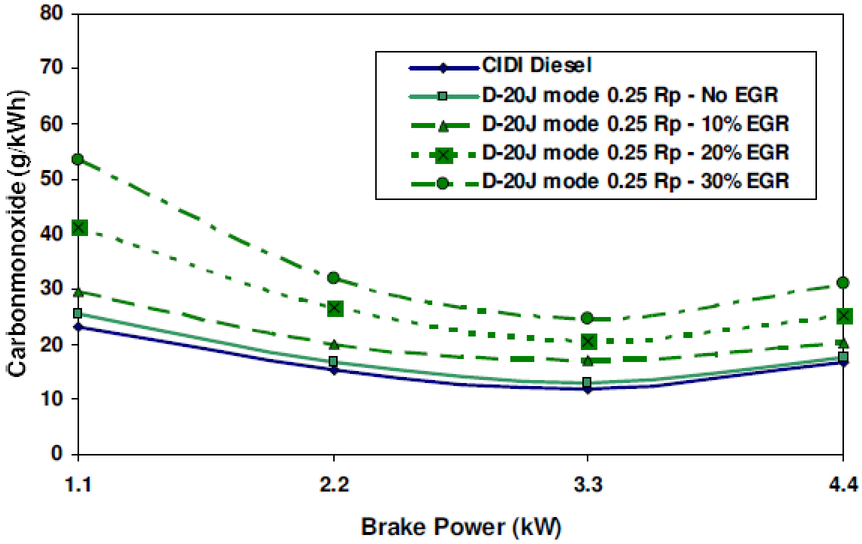

Figure 6 – Variation of Carbonmonoxide with Brake Power

Oxides of Nitrogen Emissions. Figure 7 shows the variation of NO_x emissions with brake power for CIDI mode and DPCIE mode with D-20J with 10, 20 and 30% EGR and without EGR. The combustion starts earlier resulting in higher heat release rate, in-cylinder temperature, and pressure at rated power output. These results in higher NO_x formation at rated power output for the D-20J mode with the premixed ratio of 0.25 without EGR compared to base line diesel mode. Recirculation of exhaust gas reduces the NO_x emission at all the power outputs compared to CIDI mode as oxygen available for the formation of NO_x is reduced when using EGR. Peak combustion pressure and temperatures are reduced as EGR percentage increases. At rated power output in the D-20J mode with 10%, 20% and 30% EGR the NO_x emissions range from 6.2 to 3.33 g/kWh compared to 9.1 g/kWh without EGR.

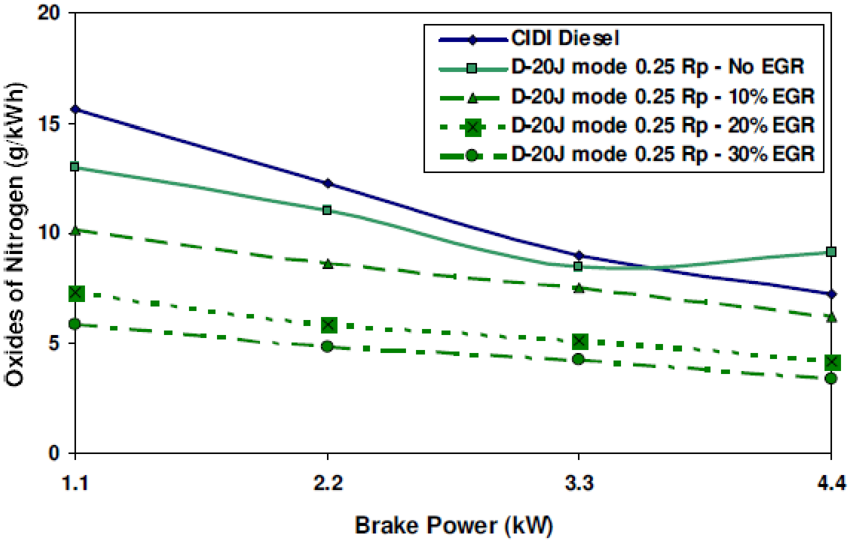

Figure 7 – Variation of Oxides of Nitrogen with Brake Power

Soot Emissions. The variation of soot emission with brake power for DPCIE mode of operation with D-20J with 10, 20 and 30% EGR and without EGR is shown in Figure 8. Soot emission in DPCIE mode with EGR is higher compared to that of without EGR. The increase in soot emission is due to the reduction in oxygen content and decrease in heat release rate with EGR at all power outputs. It is observed that with 10% EGR and 20% EGR, soot emissions are lower than that of CIDI mode but higher than

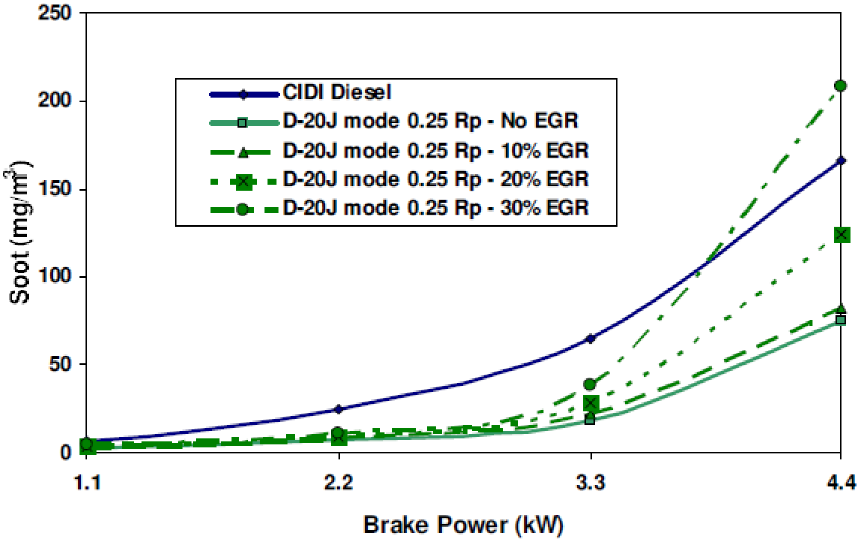

Figure 8 – Variation of Soot with Brake Power

DPCIE mode without EGR. Soot emissions are higher than that of CIDI mode when EGR is creased beyond 20%. Hence, the quantity of EGR that can be re-circulated in DPCIE mode with the premixed ratio of 0.25 is limited to 20% in the present work. In DPCIE mode, the soot emissions in the D-20J mode at rated power output vary from 82 to 208 mg/m^3 with 10%, 20% and 30% EGR while it is 75 mg/mg^3 without EGR compared to 166 mg/m^3 in CIDI mode.

Pressure-Crank Angle Diagram. Figure 9 shows the pressure crank angle diagram at rated power output for the premixed ration of 0.25 without EGR and with 10, 20 and 30% EGR in D-20J mode.

The in-cylinder pressure and temperature are reduced due to higher specific heats of CO_2 and H_2O compared to air, with EGR. The decrease in concentration limits the availability of oxygen for combustion. It can be observed that the start of combustion is retarded with increasing EGR in DPCIE mode. The peak pressure also decreases as the EGR percentage is increased. At rated power output, the start of combustion occurs between 11and 6ºCA bTDC in D-20J in the premixed ratio of 0.25 without EGR and with 10%,20% and 30% EGR compared to 7ºCA bTDC in CIDI mode.

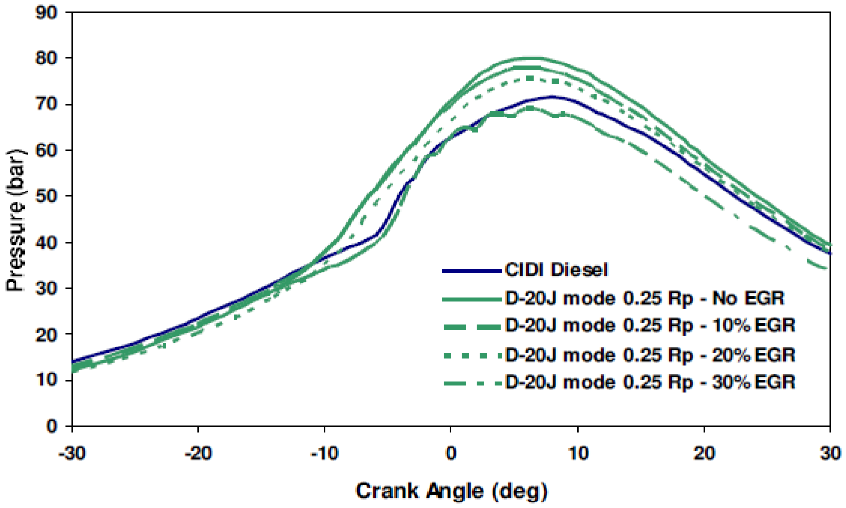

Figure 9 – Variation of Pressure with Crank Angle

Peak Pressure. The variation of peak pressure with brake power for the D-20J mode with the premixed ration of 0.25 without EGR and with various percentages of EGR is shown in figure 10. As discussed earlier combustion starts earlier and the peak pressure is high at rated power output. It can be observed

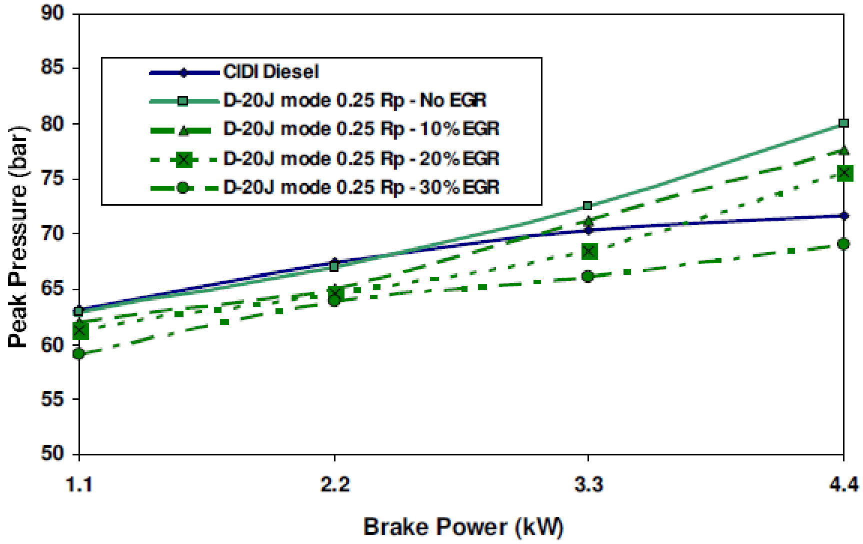

Figure 10 – Variation of Peak Pressure with Brake Power

that the peak pressure decreases with increase in EGR compared to DPCIE mode. EGR act as a thermal sink controlling the heat release rate and inhibiting rapid pressure rise. The decrease in oxygen concentration is also responsible for the reduction in peak pressure. The peak pressure varies from 77.6 to 68.9 bar with 10% to 30% EGR compared to 80.0 bar without EGR.

Heat Release Rate. Figure 11 shows the heat release rate at rated power output for various premixed ratios in DPCIE mode compared to CIDI mode. It can be observed that the heat release curves show two peaks-one smaller magnitudes and another peak of greater magnitude near TDC. The first stage of heat release is associated with low-temperature kinetic reactions (cool flames) named Low-Temperature Reactions (LTR). The second stage of heat release rate is the main heat release and named as High-Temperature Reactions (HTR). The time delay between the LTR and HTR is named as Negative Temperature Coefficient (NTC) Region.

The Negative Temperature Coefficient regime is characterized by a decrease in the overall reaction rate even though in-cylinder temperature increases. This leads to a lower reactivity of the system. For diesel (lower octane number fuel) the heat release in the Low-Temperature Combustion (LTC) is predominant compared to gasoline (higher octane number fuel).

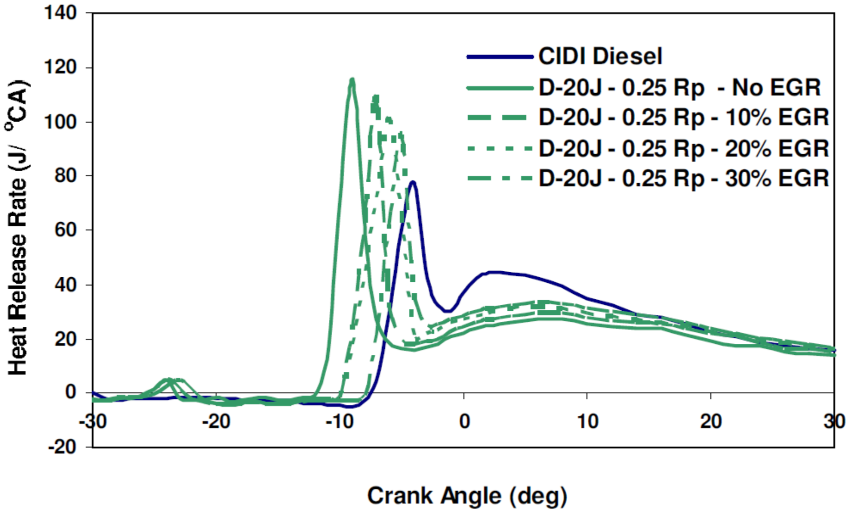

Figure 11 – Variation of Heat Release Rate with Brake Power

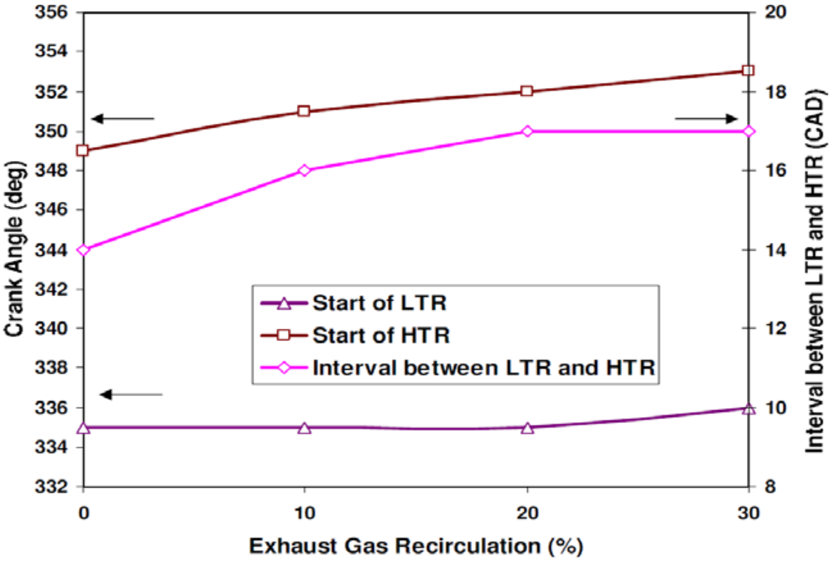

Figure 12 – LTR, HTR and Interval between LTR and HTR with Various Percentages of EGR at Rated Power Output for D-20J mode

Figure 12 shows the LTR, HTR, and interval between LTR and HTR in D-20J mode at rated power output for the premixed ratio of 0.25 without EGR and with 10, 20 and 30% EGR. It is observed that the peak LTR is not affected with increase in EGR percentage. But peak of HTR is significantly decreased as the percentage of EGR is increased. Increasing EGR percentage can delay both, the start of LTR and HTR. The EGR act as a thermal sink absorbing the heat present and lowers the heat release rate. The peak heat release rates during HTR at rated power in D-20J are 115.8, 109, 101.2 and 95.2 J/ºCA occurring at 11 to 7 ºCA bTDC for premixed ratios of 0.25 without EGR and with 10, 20 and 30% EGR while the peak heat release rates during LTR vary from 4.8 to 5.1 J/ºCA occurring at nearly 25ºCA bTDC for all premixed ratios. The time interval between LTR and HTR varies from 14 to 17 ºCA.

Conclusions. The results are summarized as follows:

– Brake thermal efficiency decreases with increase in EGR percentages.

– UBHC and CO emissions are higher in DPCIE mode.

– NO_x emissions are lower and the percentage decreases were 14.8%, 42.8% and 54.3% compared to baseline diesel mode.

– Soot emission decrease up to 20% EGR and increases when EGR increased above 20% compared to CIDI mode.

– In D-20J the peak pressure increases up to 20% EGR and decrease when EGR was increased to 30% compared to CIDI mode.

– The percentage increases in peak heat release rate in D-20J are 40.6%, 30.6% and 22.8 % compared to CIDI mode.

– The premixed ratio of 0.25 with 20% EGR was observed to be optimum in D-20J comparing the performance, combustion and emission characteristics.

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БИОДИЗЕЛЬДІ ОТЫННЫҢ ЭМИССИЯЛЫҚ СИПАТТАМАЛАРЫНА ЦИРКУЛЯЦИЯЛЫҚ ПРЕМИКС ЖӘНЕ ПАЙДАЛАНЫЛҒАН ГАЗДЫҢ ӘСЕРІ

Аннотация. Осы мақалада пайдаланылған газдардағы NO_x және қатты бөлшектердің шығарындыларын алдын-ала араластыруға арналған дизельді отты қозғалтқышты пайдалану арқылы азайту үшін әрекет жасалғаны сипатталды. Йатрофа майы (Jatropha, JOME) 20% метил эфирімен араласқан дизель отыны, негізгі отын ретінде; және дизель отыны, алдын-ала араласқан отын ретінде, су алу қондырғысына енгізілді.

Дизельді отын біртекті премикс қалыптастыру үшін алу колоннасына енгізіледі, ал цилиндрде жанармай тепе-теңдік мөлшерінде цилиндрде күйдіріледі. Эксперимент 25% премикс үшін қозғалтқыштың 10%, 20% және 30% шығатын газымен жүргізілді; нәтижелер дизель отынын қалыпты пайдалану кезінде алынған деректермен салыстырылды. Айта кету керек, негізгі инъекцияда дизельдік отын мен JOME қоспасы жақсы араластыруға және шығарындыларды азайтуға әкелді. NOx және қатты бөлшектердің айтарлықтай төмендеуі JOME-дизельді жұмыс режимінде 25% премикс режимінде және 20%-дық пайдаланылған газдың рециркуляциясымен қамтамасыз етілді. Тығыздаудың жоғары жылдамдығын жоғарылату пайызы 40,6%, 30,6% және 22,8% құрады. Шығарынды газдың 20% айналымымен 0,25 премиксі қатынасы D-20J-де өнімділік, жану және шығарындылар бойынша оңтайлы болды.

Түйін сөздер: дизель премиксі, гетрафиялық метил эфирі, азот оксидтері, пайдаланылған газдардағы қатты заттар, пайдаланылған газдардың рециркуляциясы.

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ВЛИЯНИЕ РЕЦИРКУЛЯЦИИ ПРЕМИКСА И ВЫХЛОПНОГО ГАЗА НА ЭМИССИОННЫЕ ХАРАКТЕРИСТИКИ БИОДИЗЕЛЬНОГО ТОПЛИВНОГО ДВИГАТЕЛЯ

Аннотация. В настоящей работе была предпринята попытка уменьшить выбросы NO_x и твёрдых взвешенных частиц в выхлопных газах путем использования дизельного двигателя зажигания с предварительным смешиванием. Дизельное топливо, смешанное с 20% метилового эфира масла ятрофа (Jatropha, JOME) в качестве основного топлива, впрыскивалось в цилиндр; и дизельное топливо, в качестве предварительно смешанного топлива, впрыскивалось во впускной коллектор. Дизельное топливо впрыскивается во впускной коллектор для образования гомогенного премикса, а премикс сгорает в цилиндре в равновесном количестве топлива, непосредственно вводимого в цилиндр. Эксперименты проводились с 10%, 20% и 30% отработанных газов двигателя для премикса 25%; результаты сравнивались с данными, полученными при обычной работе дизельного топлива. Было отмечено, что впрыск дизельного топлива и смесь JOME в основной инъекции приводят к лучшей подготовке смеси и снижению выбросов. Значительное снижение содержания NO_x и твердых взвешенных частиц было достигнуто при режиме премикса 25% и рециркуляции отработавших газов 20% в режиме работы JOME-дизель. Процент увеличения пиковой скорости выделения тепла составил 40,6%, 30,6% и 22,8% по сравнению с режимом прямого впрыска с воспламенением от сжатия. Было обнаружено, что соотношение премикса 0,25 с 20% рециркуляции выхлопных газов было оптимальным в D-20J, по производительности, сгоранию и выбросам.

Ключевые слова: дизельный премикс, ятрофа метиловый эфир, оксиды азота, твёрдые взвешенные частицы в выхлопных газах, рециркуляция выхлопных газов.

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