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RESEARCH OF THE USED METHYL ESTER OF VEGETABLE OIL AND ITS MIXTURES WITH DIESEL FUEL AS A FUEL IN COMPRESSION IGNITION ENGINE

Abstract. In this work researches of the used methyl ester of vegetable oil and their mixes with diesel fuel in various proportions as fuel for the purpose of studying of performance data of the engine and content of emissions were carried out. Biodiesel fuel was produced by transesterification in the presence of the catalyst of sodium hydroxide (NaOH) and potassium hydroxide (KOH) in proportions of 20% and 100% (on volume) which usually are called B20N, B100N, B20K, B100K, respectively.

The experiment was performed in the load range of 0%, 25%, 50%, 75% and 100%. It has been established that, compared with diesel fuel, when testing obtained biodiesel, CO emissions are reduced by 13.63%, 32.2% for mixtures of B20N and B100N at full load and by 4.5%, 32% for B20K and B100K, respectively. Compared to diesel fuel, biodiesel fuel and its mixtures showed a significant reduction in emissions of CO, hydrocarbons, smoke and particulate matter. However, the content of nitrogen oxides in used vegetable oil biodiesel was slightly higher than that of diesel fuel. The authors of the work conclude that the diesel engine can operate satisfactorily on biodiesel fuel and its mixtures with diesel fuel without any engine modifications.

Key words: biodiesel, transesterification, emission reduction, used vegetable oil, nitrogen oxides, diesel engine.

Introduction. In the era of global warming where the people are making their living more and more comfortable and they are deteriorating the environment also [1-3]. The world is on brink of energy crisis. The limited fossil fuel sources are increasing demand of energy [4, 5]. This associated with increasing cost of fossil fuels and the consciousness of the impacts of environmental pollution has forced a search for an alternative source of energy, which is renewable, harmless and non-polluting [6, 7]. When it comes to world, energy consumption which is drastically increased for last decade. People still depends mostly on fossil fuels to fuel their vehicles, in spite of the environment problem that flow from burning coal oil and natural gas [8, 9]. So many research works are carried out in many nations like India to search an appropriate fuel source such as solar and the wind as the great alternatives which are neat copious and on the edge of mass production in the upcoming days that always seems around the corner yet eternally out of reach [10, 11]. Nowadays, renewable energy sources of the world's supply, fossil fuels provide about 85% technologically higher which have damped the cost of renewable power sources, but technology has also kept down the price using fossil fuels and some cases reduced their unsafe effects on the environment [12, 13].

The vegetable oils gratify the major necessities for a diesel engine fuel, their suitability as alternative to diesel fuel have been consider as a topic of research. Under the biofuels generally understand the liquid fraction of vegetable origin, intended for additive in petroleum fuels or for direct use in the engine. For example, ethyl alcohol obtained from agricultural raw materials, as an energy carrier, is no different from

hydrolytic or synthetic ethanol, but its producers and consumers, for example, in the European Union countries have great preferences. This is due to the desire not only to solve the problem of expanding the fuel base, but also to stimulate its own agricultural producer. An important advantage of biofuels is the replacement of refined products with natural renewable raw materials. Therefore, the greatest attention is paid to this problem in countries poor in oil but possessing rich plant resources [14, 15]. To biofuels include ethanol, obtained by fermentation of plant materials (bioethanol), ethers, for the production of which bioethanol and methyl esters of fatty acids obtained from vegetable oils were used. According to the definition of the US standard, biodiesel fuel is understood to mean monoalkyl esters of fatty acids derived from vegetable or animal oils and intended for use in diesel engines. The main task that is being solved at the same time is the replacement of refined products with natural renewable resources [16, 17].

Thus, the rapid consolidation of biofuel positions is due to the desire to support the agricultural producer.

Compression ignition (CI) engines are more far and wide used compared to spark ignition (SI), greater thought is being committed to expand an alternative source of fuel for the CI engine. When vegetable oils are charged in a CI engine, the safety of a CI engine should be considered as a major factor. Vegetable oils and their suitability to diesel fuel as an alternative were considered as a subject of the research in [18, 19].

Biodiesel plants are not capital-intensive plants [20-23]. The majority of the cost is expended for production of biodiesel from the oil. The cost associated with catalysts such as KOH or NaOH and neutralizing acid is not important. On the other hand, there are so many indirect benefits that are possible in India. For example, in India considerable waste land is available. The energy farming by cultivation of oil bearing plants can generate employment in tree plantations; seed picking, in oil mills where extraction is carried out and then the biodiesel plant itself [24-26].

The problem of increasing demand of fuel, engine performance and emissions characteristics are greater threat to the field of automobiles. The hike in fuel cost has caused many to re-evaluate alternative fuel that has huge potential globally [27]. On the other hand, the application of used vegetable oil methyl ester in diesel engines brings into focus the various challenges that might be faced by public usage [28-30].

In a country like India, where agriculture is the main profession and kirloskar engine are mostly used by the farmers for various applications like water pumping the main problems are the increasing demand of fuel, cost and emission [31, 32]. The biodiesel is considered as an alternate fuel for diesel engines especially, during the periods of diesel scarcity.

The main aim of this research is to demonstrate how capably an engine can be run by applying used vegetable oil methyl ester (biodiesel) and its blends when compared to diesel.

The objectives of this work are to investigate the engine performance on emission of Used Vegetable Oil Methyl Ester (UVOME) which is derived through transesterification process by using the Bio-diesel Processor. The two different catalysts (KOH and NaOH) are investigated to find the emission reduction and recycling of UVOME. The biodiesel and its blends are studied and compared with diesel.

Materials and methods. Experimental tests have been performed at the single-cylinder, four-cycle, naturally aspirated and water-cooled test bench with the diesel Kirloskar engine. The diesel engine was directly connected with a vortex-current dynamometer. The engine and a dynamometer were connected to the control panel which was connected to the computer. This computerized test bench was used for reading of parameters of tests. Installation is supplied with necessary devices for measurement of pressure of combustion and an angle of rotation of a bent shaft. These signals are connected with the computer via the engine indicator for charts of pQ-pV.

All the tests were carried out when the engine was operated on UVOME, and their mixtures were obtained through a transesterification process using a catalyst (sodium hydroxide (NaOH) and potassium hydroxide (KOH)) in proportions of 20% and 100% (vol.), they are usually called B20N, B100N, B20K, B100K respectively.

Samples of biodiesel were prepared according to the scheme shown in figure 1. Methanol (molar ratio 1:3 oil:alcohol) was mixed with NaOH/KOH (1 wt.% of oil), slowly added to the reactor containing oil when mixing. Reactionary mixture is boiled with the return refrigerator within 2–4 hours. By means of TLC the completeness of reaction was checked. After the end of a reaction the produced compound was

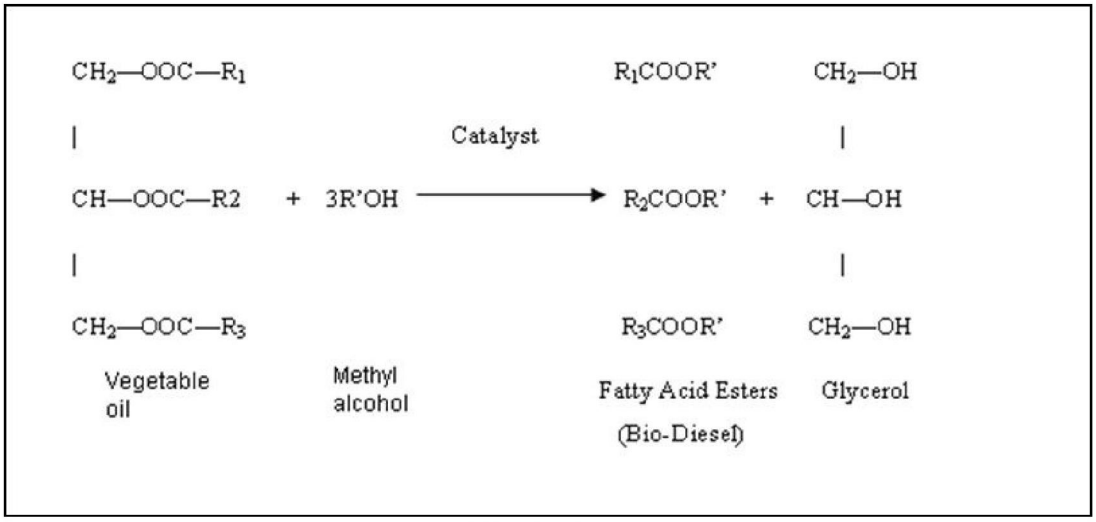

Figure 1 – A scheme of an alkali catalyzed method

transferred to a dividing funnel and both phases were divided. The top phase represented the biodiesel, and the lower part was glycerin. Alcohol from both phases was driven away in a vacuum. The glyceric phase was neutralized by acid and stored in a type of the crude glycerin. The top phase, that is methyl air (biodiesel fuel), was washed with water for removal of traces of glycerin, not reacted catalyst and soap formed during transesterification twice. Residual product was kept in a vacuum to get rid of residual moisture. Table shows properties of various mixes produced in the course of transesterification.

In this research data for loadings of 0%, 25%, 50%, 75% and 100% were obtained.

Properties of Various Blends

Fuel	Fuel Density (kg/m^3)	Calorific Value (kJ/kg)
Diesel	830	42,000
B20N	886	40,919
B100N	918	37,292
B20K	884	41,392
B100K	914	37,848

Results and discussion. In figure 2 are shown data of experiments for determination of CO emissions for diesel fuel, BN and its blends, BK and its blends at different load conditions. Obviously that CO emissions are significantly decreased in the case of introduction of BN or BK to diesel fuel. It was found that CO emission reduced from 13.6 to 32.37% for BN blends. The emission of CO reduced from 4.54 to 32% in the case of BK blends at full load condition. In this research experiments show that CO concentration in the case of biodiesel and blends is lesser for BN blends by comparison with the other fuels. BK blends demonstrated reduced CO emission than diesel.

Probably it can be because the oxygen content in biodiesel allowing more carbon molecules to be oxidized when compared with the diesel fuel.

Data on the unburnt hydrocarbon emissions for BK blends and BN blends in comparison with diesel are shown in figure 3. It was found that hydrocarbon emissions are decreased at any chosen load for BN and BK blends. The lowest content of hydrocarbons (25 ppm) is revealed for B100K, it was least than for all other examined fuels. Compared to BK fuel blends, the emission of HC is slightly on higher side in BN fuel blends. The causes of the reduction of hydrocarbon emission may be deeper combustion because of the increased oxygen content in the flame forming from the biodiesel molecules.

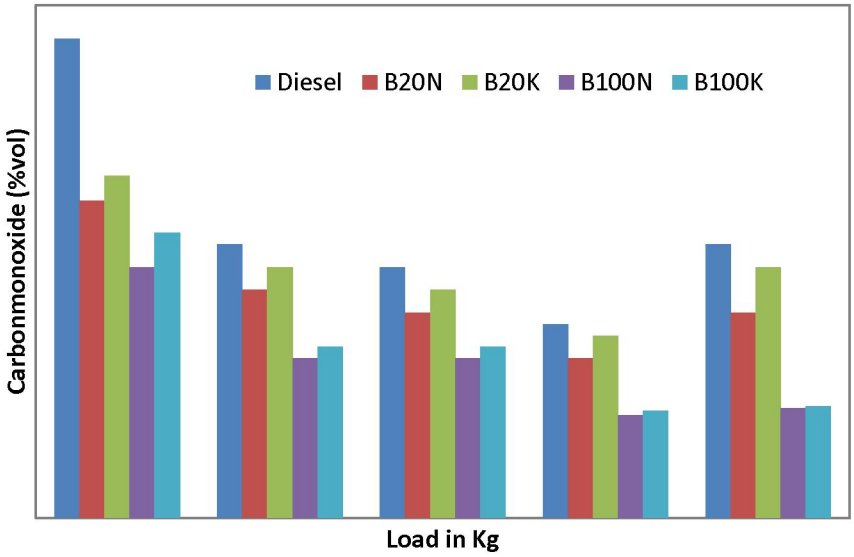

Figure 2 – Data of CO emissions for diesel, BN and BK at the different load conditions

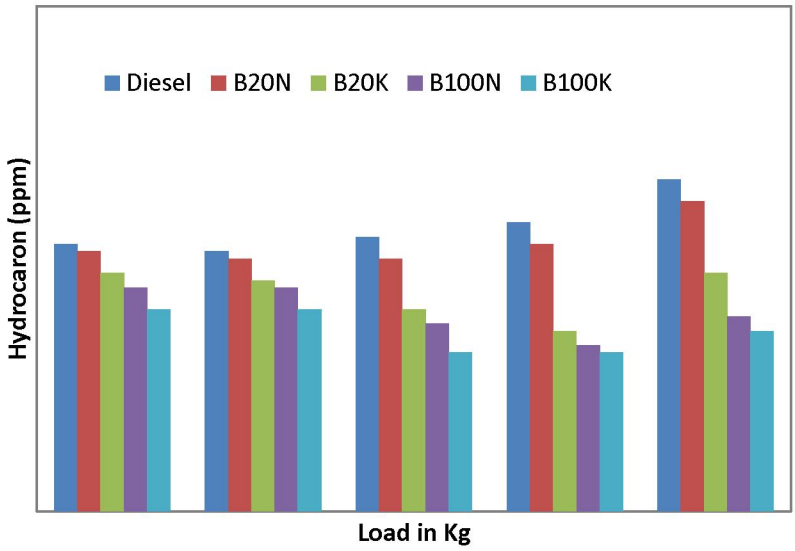

Figure 3 – Data of hydrocarbons emissions for diesel, BN and BK at the different load conditions

Data on determination of content of NO_x for diesel fuel, BN and its mixes, BK and its mixes under various conditions of loading are shown in figure 4. It is revealed that emissions of nitrogen oxides increase at addition of BN, BK in comparison with diesel fuel a little. Formation of NO_x in a cylinder of the engine is influenced by the oxygen content, temperature of burning of a flame and duration of oxidation. Formation of NO_x in all biodiesels and mixes is a little more, than in diesel fuel, and the maintenance of NOx in B100K is 18% higher, than in usual diesel fuel in the conditions of full load.

Increasing particulate matter content happened because of non-deep burning. It was found that content of PM emissions was higher for diesel fuel than for all other biodiesel blends of BN and BK. The figure 5 shows the data on particulate matter for diesel, BN and BK at different load conditions. When the blends are increased in %, the content of PM is decreased. The lowest particulate emission (0.731 g/min) was detected in the case of B100N blend. When use BN the content of PM was lesser than for BK blends.

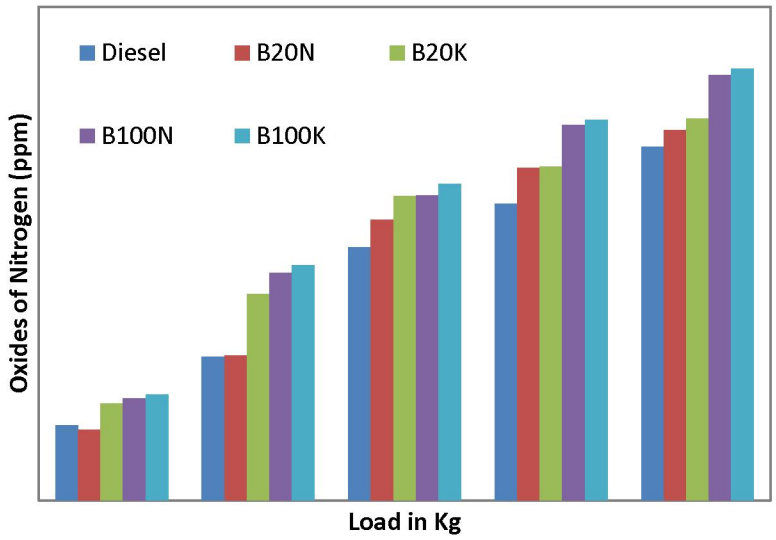

Figure 4 – NO_x emissions for diesel, BN and BK at different load conditions

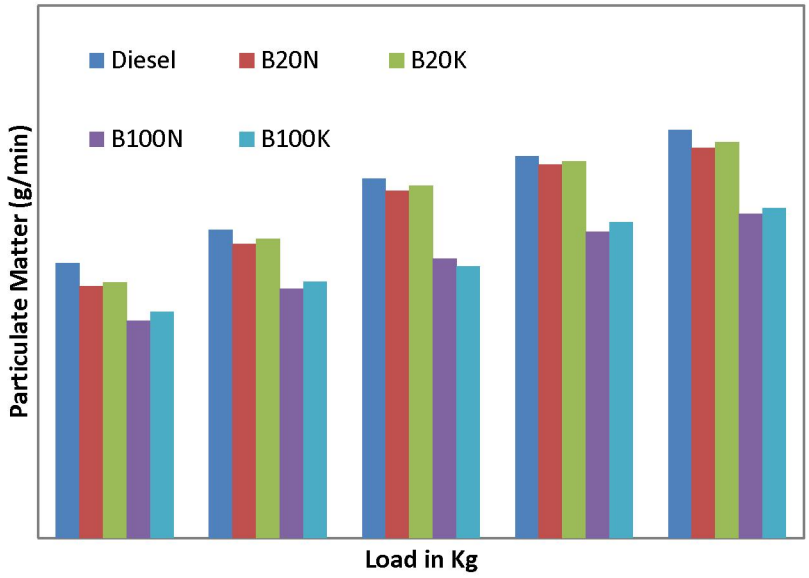

Figure 5 – Data on particulate matter for diesel, BN and BK at different load conditions

The smoke opacity of all the fuels used in this research is shown in figure 6. It was found that the smoke contents of biodiesel and its 20% blends are higher than that of diesel fuel at low and middle engine loads. Possibly, it is connected with high viscosity of the biodiesel that leads to bad dispersion and locally saturated mixes during the work with partial loading. But at high load of the engine density of smoke of all mixes of the biodiesel is lower, than at diesel fuel. It is connected with oxygen content in the biodiesel in comparison with the conventional diesel fuel.

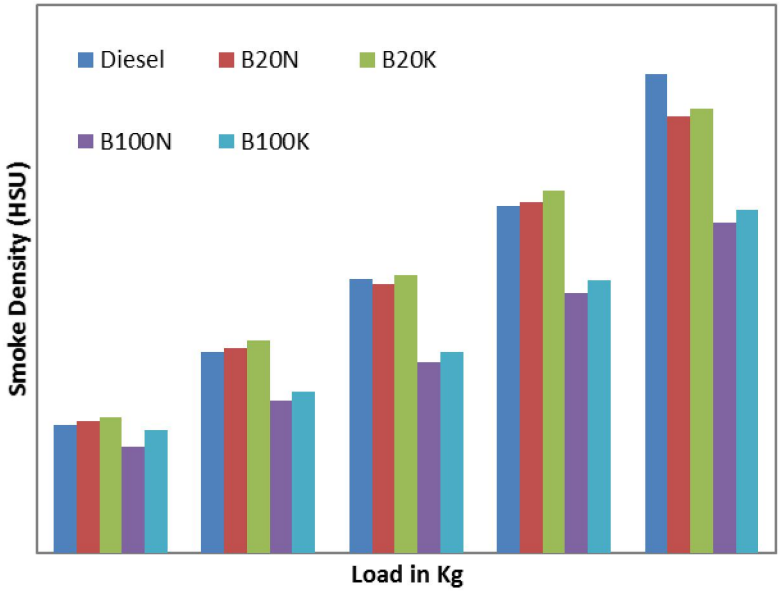

Figure 6 – Data on smoke density for diesel, BN and BK at different load conditions

Conclusions. In the work the used cooking oil methyl esters produced using KOH and NaOH, and their blends were tested as fuel and the results were compared with the emission characteristics in the case of diesel fuel.

It was found that the heating value of B20K is very close to a heating value of the diesel and the diesel engine can well work on the tested biodiesel and its mixtures with diesel fuel without any modifications of the engine. Experiments demonstrated high degree of decreasing emissions of carbon monoxide, hydrocarbons, smoke and particulate matter when apply biodiesel and its mixtures in comparison with diesel fuel. BK blends shows reduced CO emission than diesel. The lowest value of hydrocarbon emission is obtained for B100K is 25 ppm than all other fuels such as diesel, BN blends. When the blends are increased in percentage, the particulate matter is reduced. The lowest particulate emission of 0.731 g/min obtained from B100N blend. BN shows lesser particulate matter than BK blends. However the NO_x content when using the used cooking vegetable oil - biodiesel is insignificant above, than in the case of diesel fuel. We can conclude that the used methyl vegetable oil (UVOME) can successfully replace a diesel fuel for reduction air pollution.

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ПАЙДАЛАНЫЛҒАН МЕТИЛ ЭФИРІНІҢ ӨСІМДІК МАЙЫН ЖӘНЕ ОНЫҢ ДИЗЕЛЬДІ ОТЫНМЕН ҚОСПАЛАРЫН ҚОЗҒАЛТҚЫШТА ЖАҒУДЫ ЗЕРТТЕУ

Аннотация. Зерттеу барысында қозғалтқыштың өнімділігі мен шығарындыларын зерттеу үшін өсімдік майының қалдықтарының метил эфирін және дизельді отынның қоспаларын жанармай ретінде түрлі пропорцияларда зерттеу жүргізілді. Биодизельді отын, тиісінше, B20N, B100N, B20K, B100K деп аталатын 20 және 100% (көлемі бойынша) пропорцияда натрий гидроксидінің (NaOH) және калий гидроксидінің (KOH)

катализаторы болған кезде переэтерификация арқылы алынған. Тәжірибе 0%, 25%, 50%, 75% және 100% жүктеме ауқымында жүргізілді. Дизельді отынмен салыстырғанда, алынған биодизельді сынақтан өткізген кезде CO шығарындылары 13,63%-ға, B20N және B100N қоспаларының толық жүктемесінде 32,2%, B20K және B100K үшін 4,5%, 32%-ға төмендегені анықталды. Дизельді отынмен, биодизельдік отынмен және оның қоспаларымен салыстырғанда CO, көмірсутектер, түтін және қатты заттар шығарындыларының айтарлықтай төмендеуі байқалды. Дегенмен, азот оксидтерінің құрамында өсімдік майы биодизелы дизельді отынға қарағанда біршама жоғары болды. Жұмыстың авторлары дизель қозғалтқышы биодизель отынына және дизельдік отынмен қоспаларына қозғалтқышты модификациялаусыз қанағаттанарлық жұмыс істей алады деп тұжырымдайды.

Түйін сөздер: биодизель, қайта этерификациялау, өсімдік майы, азот тотығы, дизельді қозғалтқыш.

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ИССЛЕДОВАНИЕ ОТРАБОТАННОГО МЕТИЛОВОГО ЭФИРА РАСТИТЕЛЬНОГО МАСЛА И ЕГО СМЕСИ С ДИЗЕЛЬНЫМ ТОПЛИВОМ В КАЧЕСТВЕ ТОПЛИВА В ДВИГАТЕЛЕ КОМПРЕССИОННОГО ЗАЖИГАНИЯ

Аннотация. В работе проводились исследования отработанного метилового эфира растительного масла и их смесей с дизельным топливом в различных пропорциях в качестве топлива с целью изучения рабочих характеристик двигателя и содержания выбросов. Биодизельное топливо было получено путем трансэтерификации в присутствии катализатора гидроксида натрия (NaOH) и гидроксида калия (KOH) в пропорциях 20 и 100% (по объему), которые обычно называются B20N, B100N, B20K, B100K, соответственно. Эксперимент проводился в диапазоне нагрузок 0%, 25%, 50%, 75% и 100%. Установлено, что, по сравнению с дизельным топливом, при испытании полученного биодизеля выбросы CO снижаются на 13,63%, 32,2% для смесей B20N и B100N при полной нагрузке и на 4,5%, 32% для B20K и B100K, соответственно. По сравнению с дизельным топливом, для биодизельного топлива и его смесей выявлено значительное снижение выбросов CO, углеводородов, дыма и твердых частиц. Однако, содержание оксидов азота в отработанном растительном масле биодизеля было незначительно выше, чем у дизельного топлива. Авторы работы делают вывод, что дизельный двигатель может удовлетворительно работать на биодизельном топливе и его смесях с дизельным топливом без каких-либо модификаций двигателя.

Ключевые слова: биодизель, трансэтерификация, снижение выбросов, отработанное растительное масло, оксиды азота, дизельный двигатель

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