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Experimental Investigation Of Using N-Hexanol As Additive To N-Butanol/Diesel Blends In Diesel Engine To Study The Emission And Performance Characteristics

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ABSTRACT
This work describes the effect of n-butanol and n-hexnol as fuel blends to check the performance and the emission levels of a DI diesel engine for various loads at constant engine speed. The fuels proportions required to be tested are, B5H (n-butanol 5%, 10% n-hexanol along with 85% diesel in volume), B10H, B15H, B20H and B25H (Hexanol added to the blends are constant). Experiments were conducted on unmodified 4-stroke diesel engine of single cylinder and naturally aspirated one. The engine is tested in idle and various loading conditions with the help of dynamometer by using the test fuel blends. When the blends were compared with diesel fuel, brake specific fuel consumptions are higher for alcohol blends were observed. The results displayed that smoke emissions and carbon monoxide emissions reduce while HC emissions tend to increase with blend proportions present in the fuel. Increasing the blend proportions increases the NO emissions.

Keywords: n-butanol, n-hexanol, performance, emission, diesel fuel, DI-CI engine.

INTRODUCTION:

A diesel engine acts as power source for automobiles and power plants operation due to their superior fuel economy compared to petrol engines of similar capacity. Diesel engines affect the environment by emitting dangerous exhaust compounds through atmospheric air medium. They release oxides of nitrogen and smoke emissions in large quantity which tends have an impact on environment. Other pollutants from diesel engine are hydrocarbons and carbon monoxide. The exhaustion of petroleum reserves and new stringent emission rules updated regularly over the years leads to research new technologies. In order to meet emission standards substitutes such as bio-diesel, alcohol, liquefied petroleum gas and compressed natural gas are used in both SI and CI engines selectively. Besides, alcohols blended with diesel tend to reduce emissions effectively [1].

Alcohol fuels contain high oxygen and sulphur concentrations along with reduced carbon molecules compared to regular diesel fuel which are being used extensively. Blending of alcohols such as ethanol, methanol tends to offer increased oxygen concentration compared with other biodiesel blends. Higher oxygen concentrations in blends help to reduce particle emission [2]. Methanol and ethanol were used in different compositions with diesel oil to reduce engine exhaust emissions in search of substitution for diesel [1-5]. As mentioned alcohols contain high octane number compared to conventional standard diesel fuel, since it can boost the octane rating for petrol or spark ignition engines universally. They have low cetane number, which led to its restraint to use in diesel engines directly or in blended composition. Low proportions of alcohol blended to the diesel don't need modification in engine and its injector system. Experiments conducted on DI-diesel engines for observing both performance and emissions characteristics with the usage of alcohol blended with diesel oil, results in reduction of HC, CO and soot emission. However NO tend to rise due to high oxygen concentration [3].

The engine performance and emission characteristics for a variety of blend proportion made from ethanol and diesel was investigated and results in reduced brake thermal efficiency and BSFC. Significant increase in case of HC emissions on above test blends, NO tend to vary with respect to parameters selected for each test. CO and particulate emissions tend to be lower relatively but increases slightly at low load running circumstances [5]. Butanol being a long chain alcohol does have advantages greater than those short chain alcohols such as methanol and ethanol as a substitute for engines like the fuel characteristics of butanol are closer to standard diesel. Auto ignition capability of butanol is lesser, when compared with other short chain alcohols. Besides, it can be combusted with ease during the cycle operations of diesel engine. Comparatively, butanol contains high energy content and doesn't evaporate easily when compared with other alcohols. High carbon content and cetane number of butanol is higher than other alcohols makes a favourable option. Besides, it has high resistance towards corrosion and contains better calorific value than other alcohols [6]. Butanol is formed from biomass fermentation, like sub-material wastes obtained from agriculture products which contain cellulose, unusable to other consumable purposes.

Four butanol isomers, iso-butanol, tert-butanol, n-butanol and sec-butanol were tested with diesel by 20% and 40% in volume basis. The recent was Iso-butanol/diesel and the earliest was tert-butanol/diesel. All Butanol isomers reduce soot emissions compared with diesel fuel [7]. Bu20 twenty percent of butanol in volume basis blended with diesel resulted in reduction of both smoke and NO without affecting the performance of the test engine [8]. Butanol additive in croton oil along with diesel fuel results in rise of pressure cylinder and improved heat release rate when compared with diesel fuel which is the baseline. Vegetable oils used for blending with butanol and diesel tend to improve its chemical properties [9]. Tests were performed by fuel blends injected indirectly in diesel engine generator by naldir, concluded that the biodiesel–butanol blends did not show a major difference comparatively with diesel fuel for HC emissions, reduction of CO and soot was significant with slight rise in NOx [10]. Alcohol diesel blending increased HC and CO emissions and decreased NO emission comparatively higher than vegetable oil-alcohol [11]. Butanol is used as an additive not as a blend in 2, 4, 6 percentages (n2, n4, n6) with respect to diesel fuel [12].

Hexanol is an organic alcohol comes under long chain alcohols with a six carbon chain, and the carbon content in mass percentage is higher compared to butanol. Hexanol is obtained from ethanol oligomerization. It can also be obtained from agriculture wastes, an unconventional energy source. Hexanol has cetane number better than butanol and closer to standard diesel fuel [13]. Hexanol usually unconsidered for substitution for fossil based energy source, certain favourable properties made to be a chemical addition for diesel-butanol blends, the examinations was experimented with a stationary diesel engine.

TEST EQUIPMENT:

Experimental analysis was conducted in a four-stroke, liquid cooled, single cylinder, naturally aspirated and direct injection stationary CI engine. For the experiments, five fuel compositions were prepared. N-butanol was blended with diesel along with 10% of hexanol in volumetric basis and stirred to check the blend properties. Blends were prepared with 5%, 10%, 15%, 20 % and 25% of n-butanol concentrations by volume basis.

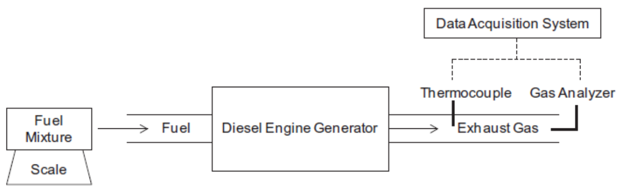

Fig. 1. Experimental set-up.

Mixtures with different concentrations of butanol and addition of 10% hexanol were observed to make sure that the solutions are stable and were used for testing the engine. Basic fuel properties for diesel, hexanol and butanol are shown in Table 1. Hexanol content in the blend is restricted, as the kinematic viscosity is high and could raise problem regarding the fuel injection, as fuel is injected through the injector at very high pressure in order to obtain proper atomization. As the entire fuel system designed for diesel, hexanol is limited to 10% in all blends. The tests were performed in idle and load conditions for each fuel type prepared for the experiment.

The fuel consumption and engine emissions were noted with help of fuel meter, gas analyser and smoke meter. Smoke emissions are measured with help of smoke meter (AVL 437c); it is connected to the engine exhaust after the analyzer section. Analyzing the exhaust gas was done by HORIBA (model MEXA-584L) gas analyser. The engine loading is provided with the help of prony brake dynamometer which is coupled to the engine

Table 1 Properties of diesel fuel, n-hexanol and n-butanol.

Properties	Diesel	n-butanol	n-hexanol
Density ($\frac{kg}{m^3}$)	835	810	820
Viscosity (cst)	3.35	2.22	5.32
Molecular weight ($\frac{g}{mol}$)	170	74	102.18
Flash point (°C)	65-88	35	68
Boiling point (°C)	180	118	175-203
Auto ignition (°C) Lower heating value ($\frac{MJ}{kg}$)	210 45	320 33.1	293 39.1
Latent heat of evaporation ($\frac{KJ}{kg}$)	250	480	840
Vapour pressure (Pa) (20°C)	300	560	100
C (% in wt)	87	64.82	70.54
H (% in wt)	13.87	13.60	13.8
O (% in wt)	0	21.59	15.66
Cetane number	45-50	25	42

Table 2 Engine specification.

Name of the manufacturer	Field marshal
Rated power	10 HP (7.35 kW)
Intake system	Naturally aspirated
Rated speed	1000rpm
No of cylinders	One
Bore	114.3mm
Stroke	139.7mm
Engine cooling	liquid cooled
Cycle of operation	Four stroke
Combustion system	Direct injection

RESULTS:

PERFORMANCE:

The result of alcohols (n-butanol and n-hexanol) blended with diesel lead to improve the BTE (brake thermal efficiency) illustrated in fig 2. Improvement in BTE was observed in few blends suitably at various loads given to the engine. The maximum efficiency obtained by the blend B25H results 17% higher compared to the diesel fuel at maximum load condition. Initial loading given to the system does have close variation in terms of efficiency for different blends. B25H seems to be higher when compared with blends B15H and B20H especially. Similar type of graph trend was obtained in other alcohol blend based papers [5, 16].

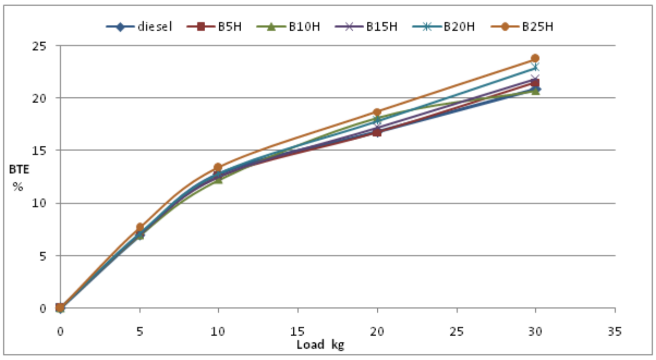

Fig.1 illustrates the BTE (%) against the engine loads for various blends of n-hexanol and n-butanol

Generally, the engine consumes large quantity of fuel with mixture of butanol and hexanol along with diesel rather compared with regular fuel for the production of similar output, due to the reduction of carbon content present in alcohol blends. Raise in alcohol concentration in diesel fuel blends results in higher consumption of fuel to deliver similar output of engine. In adding together both butanol and hexanol in different blending proportions, B5H and B10H the brake specific fuel consumption are closer to diesel [14, 16]. B15H, B20H and B25H clearly showed significant raise in BSFC with respective to engine loading conditions. Addition of N-butanol along with n-hexanol in diesel blends tends to increase BSFC clearly.

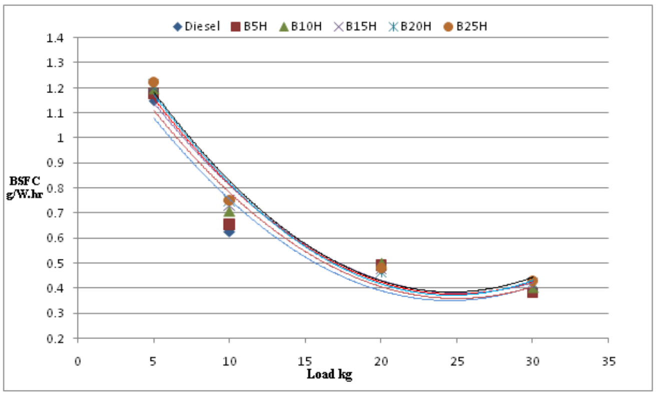

Fig.2 illustrates the BSFC (g/W hr) with various blends of n-hexanol and n-butanol

ENGINE EMISSIONS:

NO:

It was observed that emissions of NO were varied with alcohol blend proportions while the engine was tested by varying the loads. The existence of oxygen concentration along with high temperature inside the combustion chamber has major consequence towards formation of NO. Rising oxygen concentrations of the n-butanol and n-hexanol on diesel fuel blends tend to produce NO emissions. N-hexanol has high calorific value but because of its high viscosity fuel atomization is affected and at low load conditions the NO formed in the engine is lower than diesel fuel. By increasing the n-butanol concentration in blends tend to provide high oxygen content lead to increase the NO formation for all fuel blends. It is observed that blends have lowered NO formation compared with diesel fuel at initial loading. Further, B15, B20 and B25 rises above steeply compared to diesel [13]. Consequently, the emitted NO of combined n-butanol and n-hexanol fuel blends are higher than diesel fuel shown in fig 3.

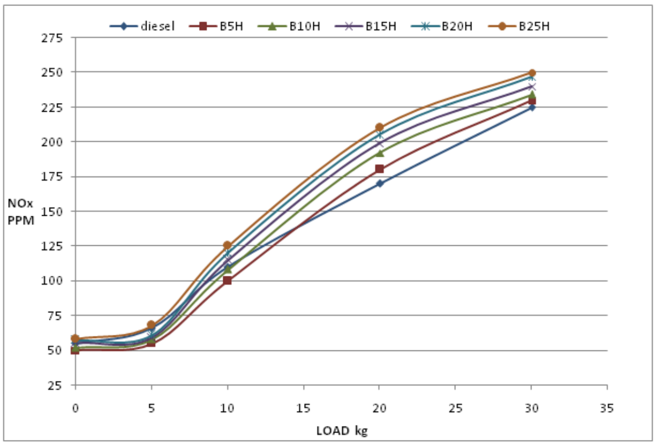

Fig.3 illustrates the NO for various blends of n-hexanol and n-butanol.

HC:

Evaluation of unburned hydrocarbon emissions for alcohol fuel blends are shown in Fig 4. Experimental results showed that n-butanol and n-hexanol added to the diesel fuel for various blend proportions emit higher HC pollutants compared to diesel fuel. HC emissions are majorly produced by shared effect of Low cetane rating along with the evaporation effect takes place in fuel blends due to elevated temperature during diesel engine operations. As the result of cetane rating present in n-butanol and n-hexanol tend to reduce the peak combustion temperature which leads to boost the HC emissions. HC emission elevates with increasing n-butanol concentration along with constant additive of n-hexanol concentration in fuel blends respectively [19].

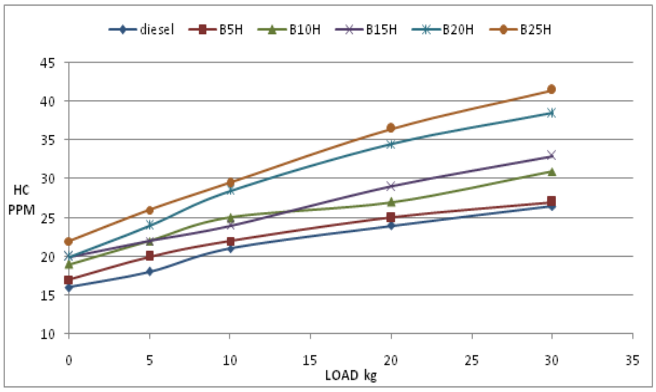

Fig.4 illustrates the HC for various blends of n-hexanol and n-butanol

CO:

As shown from fig.6, the comparison of CO emission levels for alcohols n-butanol and n-hexanol added to diesel fuel in various proportions to study the engine out emissions with help of various loading conditions. CO emission levels released from the diesel engine for diesel fuel were elevated by increasing the loading condition given to engine. Results clear that CO emissions tend to reduce with increasing n-butanol and n-hexanol. The higher oxygen content of n-butanol and n-hexanol diesel blends is capable to improve the oxidation condition of CO and results in lower CO emissions.

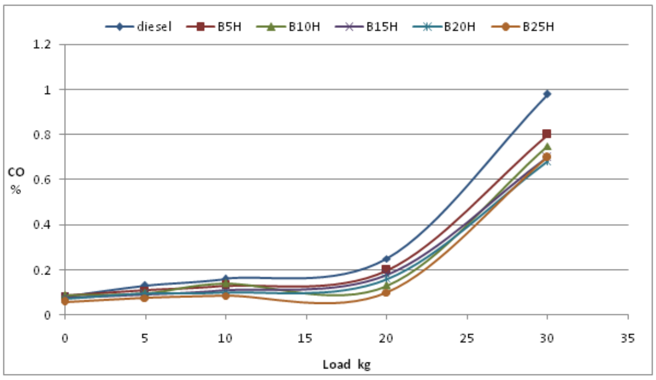

Fig.5 illustrates the CO for various blends of n-hexanol and n-butanol

Smoke emissions:

They are produced due to the deficiency of oxygen present in fuel blends. Smoke emission of blends containing alcohols compared with different loads in the engine as shown in Fig 6. The experimental results smoke emission levels were lowered with respect to increasing alcohol content in different blends (10% hexanol of constant volume proportions in all blends). The smoke reduction is due to high oxygen presence in blends with reduced carbon concentration in n-hexanol and n-butanol fuel blends. Besides, soot producing capability reduce when fuel contain high oxygen content, n-butanol and n-hexanol diesel blends is capable of improving the oxidation condition which results in lower smoke levels than diesel fuel.

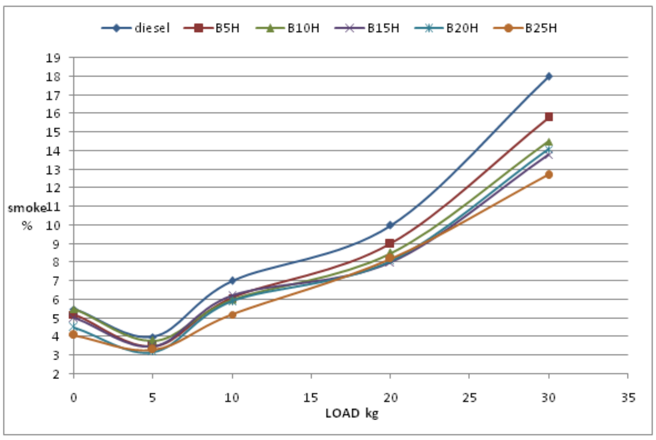

Fig.6 illustrates the Smoke emissions for various blends of n-hexanol and n-butanol.

Conclusion:

Experimental analysis of the engine emissions and performance levels of compression ignited diesel engine were experimented in steady state condition with various loads given to the engine along with idle condition with the help of alcohols n-butanol and n-hexanol blended in diesel oil. The investigation resulted alcohol blends does have significant outcome in engine emission and performance characteristics. The subsequent results from the experimental work given below are:

- N-butanol and n-hexanol blended with diesel have a tendency to raise the brake specific fuel consumption, by increasing alcohol concentration in various blend proportion tend to improve the BTE compared to standard diesel.
- The emissions of NO reduced initially with alcohols added in fuel blends, but the emission levels raises while alcohol content in fuel blend increases.
- HC emissions were increased with rising alcohol concentration in fuel blends.
- CO emissions decreased with increasing alcohol concentration in blends.
- Smoke emission was notably reduced corresponding to diesel fuel for respective blends of alcohols

Alcohols like n-hexanol and n-butanol blended to diesel could be applied in any CI engines to reduce engine emissions levels, in particular for smoke and CO levels. NO emissions tend to vary along with blend concentrations respectively.

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