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Castor and Mahua Oils Based Performance and Emission Analysis in a Biodiesel Engine Using ANOVA Technique

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ABSTRACT

Many research of Alternate fuels has been done without modification in existing compression ignition engine. The current research is based on mixing of castor & mahua oils to produce the biodiesel using trans-esterification process by adding ethanol in the presence of catalyst KOH. The performance was then analysed in single cylinder CI engine by blending produced biodiesel with commercial diesel using RSM approach & the tool used was design expert 6.0.8. It has been observed that the emission parameters are reduced to 30 % with enhanced performance parameters.

Keywords: Castor Oil, Mahua Oil, Biodiesel, Emission parameters, Performance parameters, Response Surface Methodology (RSM), Desirability Approach, Catalyst KOH, Validation of Experiments

1. Introduction

Recently, thousands of statistical experimental possess been carried out on data compression ignition engine with the use of optional fuels. Primarily the effect associated with diesel essential oil blends within the power, torque and exhaust emission is actually tested A review of the work officially done in the field of IC ignition engine with elective fuels is portrayed in this section.

Al- Hasan [2003] [1] the experimental research shows that torque, volumetric, brake power, brake thermal efficiency (BTE) and energy consumption revealed lower improvement when diesel-ethanol blend is chosen for CI engine. Results additionally shows that brake specific fuel consumption as well as air–fuel ratio was decreased. Best results are seen when we use E20 at any speed ofengine.

Xing-cai Lu et al. [2005][2] Dimethoxy methane (DMM), ethanol and dimethyl carbonate (DMC) are chosen to mix with conventional diesel fuel for experiment. Experiment shows that timing delay in ignition is increased with the increase of oxygen content in the fuel blend. As we increase oxygen volume in the fuel blend and decrease the load on engine, there is increase in HC emission at all operating range of engine.

For solving this issue, the improver of cetane number was included in the 15% ethanol- diesel fuel combination. Consequently, the CO and HC emissions in overall working ranges decrease substantially and even (NOx) emissions further decreases.

2. Related Work

Shenghua Liu et al. [2010] [3], stated that diesel-ethanol combined fuel gets the potential to lessen diesel engine exhaust smoke cigars and particulate emission in addition to help in solving the energy need. Moreover, along with the increase on the ethanol small percentage of the mixes, the engine combustion will undoubtedly be affected significantly due to the change of blend virtue. Shenghua Liu looked into the consequences of EHN for the fuel economy, combustion and emissions by using an E30-fueled engine.

Lu Xing et al. [2010] [4] looked into the actual effect involving improver of cetane number upon release rate of heat and in addition emissions in the DI engine fuelled with ethanol- diesel mixer. The outcomes display that this (BSFC) upgraded, the diesel equivalent BSFC decreased.

Lu Xing deducted;

1) Raised BSFC, nevertheless equivalent BSFC decreased for diesel and the BTE enhanced amazingly whenever diesel engine fuelled with mixes. Improver of CN shows a good effect on BTE alongside fuel ingestion.

2) Smoke emissions along with NOx lowered at exactly the same time when diesel engine determined with mixes; as well as the smoke and NOx emissions additional decreased while CN improver was initially put into mixes.

T Zhu, CS Cheung, WG Zhang [2010] [5] Exhaust properties of your CI engine fuelled with bio-diesel and also bio-diesel mixed with methanol and ethanol. The mixed-up fuels can result in reduction with both NOx and exhaust emissions of any diesel engine, with the methanol blends becoming more effective compared to ethanol combines. The use of five per cent blends might reduce the HC and CO, and increases the braking mechanism thermal effectiveness as well, nevertheless the effectiveness for NOx along with particulate cutbacks are more efficient with rise of alcoholic beverages in the combinations. With the DOCTOR, the HC, CO in addition to articulate emission scan be more reduced.

F. Gomez-Cuenca et al. [2013] [6], studied propylene glycol ethyl spirit (PGEE), dipropylene glycol methyl ether (DPGME), propylene glycol methyl ether (PGME) as oxygenated additive to determine their own effect on both the conventional diesel fuel powered attributes and the deplete emission from the diesel mixed with additive (NOx, CO, smoke and unburnt hydrocarbons).

W. M. Yang et al [2014] [7] Introduced fuel emulsifier as (Diesel + Water + Nano organic additive) (82.4% + % + 12.6%) by volume in his do the job. Unlike some other emulsion fuels (Colour-milky) developed all over the world, it's color is green and incredibly stable in nature. That is because of the phenomenon called micro-explosion.

The results mentioned that a much better BTE may be accomplished while using emulsion fuel because of the aftereffect of micro-explosion of normal water droplets. At exactly the same time, emission of NOx is certainly reduced due to the presence of normal water,which gives down the top flame temperature.

Rashedul H K [2014] [8] The result of additives made artificially on qualities, working plus emission regarding CI engine fuelled with biodiesel. Diethyl ether and even ethanol will also be useful to lessen smoke opacity. The low heat properties involving biodiesel powers are less beneficial than diesel engine fuel. But blending by using additives such as ethanol, methanol and chill flow improver additives boosts the cool flow overall performance.

Li Ruina et al. [2014] [9] Explained that biodiesel-methanol, that have high oxygen content material, are highly reliable alternate fuels of diesel engine unit. If combined, the ignition procedure for diesel engine will be improved and also reduce particulate matter efficiently. The cetane range is improved by 2-methoxyethyl ether, cyclohexyl nitrate and 2-ethylhexyl nitrate.

1) Cetane range of M10B90 raises to 57.5, 63.5, 49.3 by adding cetane variety improvers, as the thickness and viscosity change at a small rate.
2) By adding the improvers, the ignition holds off amount of diesel engine is definitely lowered for 1-3 CA plus the ignition time is definitely reduced for 1-6 CA.

Alpaslan Atmanli et al. [2014] [10] High oleic acidity content of hazelnut oil makes it an important source to be used as biofuel in diesel engine. When compared to transesterification, microemulsion is really a more practical viscosity reduction technique and not much time-consuming method.

Research Gaps

Following a comprehensive research of the current literature, numerous gaps happen to be observed in overall performance evaluation associated with internal ignition engine utilizing alternative fuels.

a. Materials review shows that investigation had been performed using mixing of biodiesel with additive but restricted work continue to be reported in blending combining with castor-Mahua oil.
b. Castor oil used with different blends has been done but no work is reported using castor –Mahua oil using RSM.

3. Objective of the Current Work

1) Response Surface Methodology (RSM) approach used to optimise the engine overall performance and also for evaluating the intraction and optimization the response.
2) Design of experiment-based technique will used to minimizing the number of experiments to effectiveness.
3) Make an effort to raise the brake thermal efficiency (BTE) , mechanical efficiency(ME) and decrease in brake specific fuel consumption (BSFC), CO, CO2 HC and NOx employing blend fuel with castor-Mahua oils.
4) Effect of castor and Mahua biodiesel,blends on the performance of engine is studied.
5) Desirability approach is used to find out optimum solution

3.1 Test Setup

It comprises of a 4-stroke, single cylinder variable compression ratio(VCR) ignition engine test bed water cooled with electric dynamometer. The torque applied to engine with electrical eddy current dynamometer device. They will consist of control unit from where all the readings can be found out during the experiment and further with help of these readings, we can made analysis about various parameters of engine. The block diagram of the test setup is as shown in fig 1 and the various blended fuels to be tested sre shown in fig. 2.

Fig 1. Test setup single cylinder VCR engine

Fig2. Various fuel blends in different proportions

3.2 Developed Model Analysis

Design of the experiments is completed with the assistance of Response surface methodology (RSM). To select the proper model and therefore formation of response surface are done by a software known as "Design Expert (DX-6.0.8)". By using experimental info (Table-1) Regression equations were shaped and effect of control variables on the response variables is studied. The various experiments is to be performed by designing the various combination of variables using response surface methodology and the values of output parameters are written in table 2.

Table 1: Selection of input variables

Sr. No	**Variable**	**Unit**	**Minimum Level**	**Maximum Level**
1	TORQUE	N-m	4	12
2	BLEND	%	5	20
3	CR	V/V	16	20

Table 2: Experimental design Table of input variables and Response

Std	Run	Block	Factor 1 A:Blending Rat % v/v	Factor 2 B:Compression % v/v	Factor 3 C:Load torque N-m	Response 1 BSFC g/kWH	Response 2 BTE %	Response 3 Mechanical Eff %	Response 4 Unburnt HC ppm	Response 5 CO % by volume	Response 6 CO2 % by volume	Response 7 NOx ppm
1	10	Block 1	17.80	19.41	5.17	564	9.7	14	28	0.21	2.73	35
2	6	Block 1	17.80	16.59	10.83	765	11.5	16	13	0.27	2.83	62
3	2	Block 1	7.20	19.41	10.83	1293	11	29	21	0.15	2.95	47
4	4	Block 1	7.20	16.59	5.17	542	12.5	32	19	0.17	2.51	69
5	11	Block 1	5.00	18.00	8.00	1002	20.8	19	20	0.22	1.87	57
6	8	Block 1	20.00	18.00	8.00	742	11.6	28	13	0.26	2.84	61
7	1	Block 1	12.50	16.00	8.00	592	13.7	18	17	0.14	3.82	47
8	3	Block 1	12.50	20.00	8.00	764	9.2	29	22	0.23	2.91	29
9	12	Block 1	12.50	18.00	4.00	854	13	27.6	19	0.19	3.99	52
10	5	Block 1	12.50	18.00	12.00	1257	11.8	14	21	0.22	2.71	48
11	15	Block 1	12.50	18.00	8.00	963	21	17	20	0.17	3.21	38
12	13	Block 1	12.50	18.00	8.00	982	19	18	19	0.19	3.92	44
13	7	Block 1	12.50	18.00	8.00	992	16	17	17	0.18	3.83	49
14	9	Block 1	12.50	18.00	8.00	1092	17	18	19	0.17	3.93	47
15	14	Block 1	12.50	18.00	8.00	962	19	20	22	0.2	3.62	33

3.3 Optimal Solutions

The goal of optimization is to search a set of satisfactory situations that satisfy all the aims. It is not compulsory that desirability is continually equal to one. Desirability must fluctuate within range of upper and lower edge of parameters which depend upon the nearness to actual value. An optimal result can be gained after agree the limits for changed design point of response parameters viz. BTE,ME , BSFC,CO,CO2,HC and NOx via the statistical software. The optimal solution having high desirability for given conditions is nominated for desired responses. Tables 3 shows the optimal conditions with higher desirability function essential for obtaining desired response characteristic under specified constraints.

Table 3: Optimal Solutions obtained using Desirability approach

Number	**Blending Ratio %**	**Compression Ratio v/v**	**Load Torque (Nm)**	**BSFC g/kwh**	**BTE %**	**ME %**	**HC ppm**	**CO % vol**	**CO2 % vol**	**NOx ppm**	**Desirability**	
1	8.20	16.59	6.30	636.141	15.338	24.0803	19.50	0.15826	2.88665	57.8473	0.563	selected

4. CONFIRMATION TEST RESULTS

Various experiments were performed for confirmation so as to confirm the optimal solution given by desirability approach as shown in table 4. Confirmation test was done for four times at torque of 6.30 Nm and blend of 8.20% by volume. Desirability value of 0.563 shows the excellent relationship between the all response constraints. Desirability can have the maximum value of one which shows an ideal case. Authentication of optimal condition is done to determine the model actual behaviour. Actual results are equated with optimum solution to analyze the errors among the predicted v/s actual parameters.

Table 4. Validation of optimum results

S.No.	**Torque (Nm)**	**CR**	**Blend (%)**	**BSFC (g/Kwh)**		**BTE (%)**		**ME (%)**		**CO (% Vol.)**		**HC (PPM)**		**CO2 (% Vol.)**		**NOx (PPM)**	
				Pred.	**Act.**	**Pred.**	**Act.**	**Pred.**	**Act.**	**Pred.**	**Act.**	**Pred.**	**Act.**	**Pred.**	**Act.**	**Pred.**	**Act.**
1	6.30	16.59	8.2	636.16	676.2	15.34	14.25	24.08	22.15	0.158	0.168	19.50	20.85	2.887	3.120	57.84	61.85
2	7.95	19.41	7.2	1014.13	1098.6	16.16	14.95	27.95	25.85	0.222	0.235	19.61	21.55	2.804	3.165	43.72	47.15
3	8.01	19.41	7.2	1019.45	1108.4	16.11	14.81	27.97	25.90	0.220	0.230	19.62	21.58	2.810	3.101	43.69	47.05

4	7.93	19.41	7.2	1011.05	1109.2	16.13	14.63	27.83	24.95	0.221	0.240	19.64	21.60	2.823	3.102	43.35	46.90
5	Average of actual value			1003.10		14.66		24.71		0.217		21.52		3.195		50.73	
6	Error % b/w pred. and actual (Pred-act../ Pred.)			-6.29%		7.10%		8.01%		-6.32%		-6.92%		-8.07%		-6.93%	

5. Conclusions

From the results of this work, the following conclusions are found after various blending of biodiesels obtained from Castor & Mahua oils:

1. Optimum conditions were obtained using the desirability approach with engine load torque 6.30 Nm and fuel blends of 8.20% (4.10% caster+ 4.10% Mahua) by volume which gives the 15.338% BTE ,24.08% ME and 636.141g/Kwh BSFC.
2. Models for all desired responses such as BTE, ME, BSFC, CO,CO2, HC and NOx were statistically significant by the ANOVA table.
3. High desirability value of 0.563 was obtained for desired response parameters.
4. After the validation of optimum results, predicted and actual values were compared to find the errors which is found to be 6.29% in BSFC, 8.01% in ME,7.10% in BTE, 6.32% in CO, 6.92% HC, 8.07% CO2 and 6.93% NOx.

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