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Analysis and Optimization of Performance Parameters in Computerized I.C. Engine Using Diesel Blended with Linseed Oil and Leishmaan's Solution

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Due to environmental concerns, the use of alternative fuel is rapidly expanding around the world, making it imperative to fully understand the impacts of diesel on pollutant formation. The aim of this work is to increase the engine performance with reduced emissions using diesel blends from different feed stocks and to compare that with the diesel. In the Indian context linseed can play an important role in the production of alternative fuel using diesel. The climatic and soil conditions of India are convenient for the production of linseed crop. The blend is prepared from diesel, linseed oil and Leishman's solution by stirring process. The performance study of a diesel engine with these diesel blends were carried out at different compression ratios and loads. The combustion performance parameters like Mechanical, Volumetric, Brake thermal efficiencies and Specific Fuel Consumption are all noted. By applying Grey Relation Analysis, the best running condition for the engine within the chosen range are decided. The sample containing 95% diesel with 3%linseed oil and 2% solution gives better performance at a compression ratio of 18 during high load conditions.

Keywords: Diesel blend, linseed oil, performance test, Grey Relation Analysis.

1. Introduction

M. P. Sharma et al [1] experimented with the Biodiesel, derived from the trans–esterification of vegetable oils or animal fats. It is composed of saturated and unsaturated long-chain fatty acid alkyl esters. In spite of having some application problems, it is being considered as one of the most promising alternative fuels in internal combustion engine. The work presented a comprehensive review of engine performance and emissions using those biodiesel. The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value and it increased fuel consumption. R. Vallinayagam et al [2] emanated the conceptualization to improve the performance and emission characteristics of diesel engine fueled with biodiesel, by altering the fuel properties through the addition of additive 1,4–Dioxane (a multipurpose additive). It has been zeroed in as one of the indispensable additive to be added with the optimum blend of KME (kapokmethyl ester), a biodiesel produced from under-utilized kapok oil. Interestingly, all the reported emissions for B25 with additive were much lower than diesel fuel, making it as one of the appropriate fuel blend for diesel engine. Michelle Sergent et al [3] improved engine performance through better fuel efficiency and reduced exhaust emissions, through the blending of petro diesel, biodiesel, bioethanol and water in various proportions. This focuses specifically on the production of biodiesel fuels by supercritical (Sc) TG ethanolysis within a global analysis –feed stocks–conversion–engine. Hence, non-catalytic supercritical ethanolysis of TG, combined with —glycerol valorization and —materials (feed stock residues/ glycerol/ biodiesel) heat power cogeneration admitting all these feed stocks is thus a viable conversion process for reaching the objective of a sustainable biodiesel alternative.

S. Jayaraj et al [4] identified that the lower blends of biodiesel increase the brake thermal efficiency and reduce the fuel consumption. The exhaust gas emissions are reduced with increase in biodiesel concentration. The production and characterization of vegetable oil as well as the experimental work carried out in various countries are summarized. The two-step esterification process converts the crude high FFA rubber seed oil to a more suitable form of fuel for diesel engines. Md. Abul Kalam et al [5] proved that a complete substitution of petroleum derived fuels by biofuel is impossible from the production capacity and engine compatibility point of view. Some guidelines on dedicated biofuel engine are prescribed. The hunt for an alternative clean fuel is vital. Till date energy from wind, solar, tidal and fusion are all very prospective type of renewable energy. Tripathi Neha et al [6] searched viable alternatives to the fossil fuel. FAME (Fatty Acid Methyl Ester) an environment friendly alternative, commonly produced by the transesterification process may be termed as biodiesel because of the characters like high flash point, biodegradable, nontoxic, etc. This attempt compares two production process viz. base catalyzed and two stage acid–base catalyzed for two possible feed stocks viz. sunflower oil and cottonseed oil, using methanol with catalysts sodium hydroxide and potassium hydroxide.

Alexandra Gruia et al [7] evaluated the characteristics of linseed oil to determine whether that could be exploited as an edible oil. Petroleum ether extraction of linseeds produced yields of 30% (w/w) oil. The chemical composition was found to contain high levels of linolenic (53.21%), followed by oleic (18.51%), and linoleic (17.25%), while the dominant saturated acids were palmitic (6.58%) and stearic (4.43%).Regarding fatty acid composition, the saturate composed an average of 11.01% of the total fatty acids and of 88.97% unsaturated acid. The major saturated fatty acid was palmitic (16:0) and stearic acid (C18:1).The major unsaturated fatty acid in the oil samples was linolenic (18:3), followed by oleic (18:1) and linoleic (18:2). Chauhan. Y. Rita et al [8] investigated about the production of renewable energy globally since it is increasingly understood that first generation biofuels, mostly oil seeds are limited in their ability to achieve targets for biofuel production, climate change mitigation and economic growth. This work assesses and integrates about the different tree borne oilseeds, extraction of oil, biodiesel processing and effect of different parameters on production of biodiesel.

A.K.Pradhan et al [9] studied the production process, fuel properties, oil content, engines testing and performance analysis of biodiesel from karanja oil which is known as Karanja oil methyl ester (KOME). The oil extraction was found 35% by n–hexane method. Lower calorific value indicates more oil consumption. The specific gravity, kinematic viscosity of B20 and B40 blends is much closer to diesel. At higher load maximum brake power was observed for B20 blend. BSFC reduces with increase in load, BTE shows better result than diesel. Incomplete combustion of KOME is much lower than diesel which was indicated in smoke opacity curve. M. Pandian et al [10] aimed at investigating the effect of injection system parameters such as injection pressure, injection timing and nozzle tip protrusion on the performance and emission characteristics of a twin cylinder water cooled naturally aspirated CIDI engine. Biodiesel, derived from pongamia seeds through transesterification process, blended with diesel was used as fuel. The experiments were designed based on response surface methodology (RSM).The resultant models of the response surface methodology were helpful to predict the response parameters. S. Naga Prasad observed that 25% of neat oil mixed with 75% of diesel is the best suited blend, without heating and without any modification of the engine. Methyl ester of Linseed oil is the better performing fuel due to better performance and lower emissions compared to other chosen methyl esters. Brake Specific Fuel Consumption for linseed oils is increased compared to diesel at rated load and is result of delay in ignition process.

2. Experimental set up

2.1. *Blending of fuel*

The blends of varying proportion of linseed oil, lieshman solution and diesel were prepared, analyzed and compared. From properties and engine test result it can be established that oil can be substituted for diesel without any engine modification and without preheating of the blends. The various blend proportions chosen for the present work are listed in the Tab. 1. The blending process followed is called "stirring method".

Table 1 Combinations used in the experiment

Sample	Proportions
S1	1000ml of D
S2	950ml of diesel + 30ml of LO +20ml of LSS
S3	900ml of diesel + 50ml of LO + 50ml of LSS
D- Diesel; L- Linseed oil; LSS - Leishman's solution	

Table 2 Property values of the various blends of the diesel

S. No	Properties	S1	S2	S3
1	Flash Point (°C)	57	35	47
2	Fire Point (°C)	65	43	55
3	Density (kg/m^3)	800	817	829

2.2. *Engine setup*

The setup consists of single cylinder, four stroke, Multi–fuel, research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed *tilting cylinder block* arrangement. The various specifications of the engine is given below.

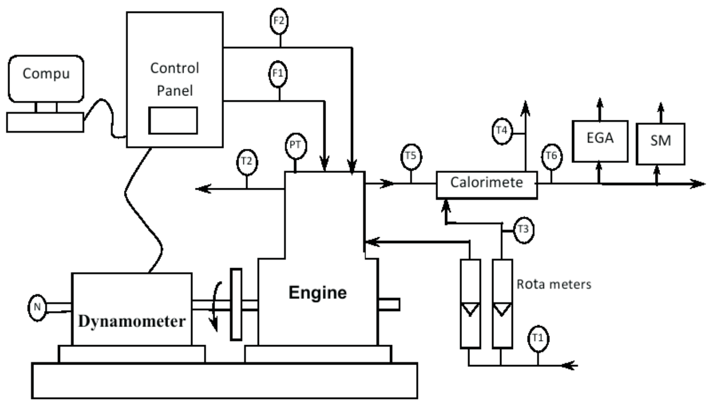

Figure 1 Layout of the engine set up

2.2.1. *Engine specification:*

1. EngineType: 1 cylinder, 4 stroke, stroke 110 mm, bore 87.5 mm
2. Capacity: 661 cc
3. Dynamometer: Type eddy current, water cooled, with loading unit
4. Propeller shaft: With universal joints
5. Fuel tank Capacity: 15 lit, Type: Duel compartment, with fuel metering pipe
6. Calorimeter Type: Pipe in pipe

7. Load indicator: Digital, Range 0-50 kg, Supply 230 VAC

8. Load sensor: Load cell, type strain gauge, range 0-50 kg

9. Software: "Enginesoft" Engine performance analysis software

10. Rota meter: Engine cooling 40-400 LPH; Calorimeter 25-250 LPH

11. Pump Type: Monoblock

12. Overall dimensions: W 2000 x D 2500 x H 1500 mm

2.3. *Input parameters combination*

The input parameters chosen for the present study are the fuel sample, compression ratio and load. There are other parameters also available for combustion process study. But the chosen parameters seem to have significant effect on combustion. There are three levels in each of the input parameter. This leads to a combination of 27 experimental runs following the full factorial design approach. The various combinations of the input parameters are listed in Tab. 3.

3. Results

The output parameters of Specific fuel consumption, Brake thermal efficiency, Mechanical efficiency and Volumetric efficiency are noted. These outputs are more desirable than the rest responses because of higher degree of performance is achieved through improvising them. The experiment were conducted in the order as mentioned in Tab. 3. The output values are listed in the table 4. It is found that the performance of diesel engine is good at compression ratios 17:1 and 18:1. Whereas it is not up to the expected level at the compression ratio 17.5:1.

3.1. *Specific fuel consumption*

The specific fuel consumption of the diesel engine must be lower in order to attain high performance. The Fig. 2 is drawn according to values obtained from the tests conducted. From the plot, it is clear that the sample 2 (containing 95% diesel with 3% linseed oil and 2% leishman's solution) has lower SFC at a compression ratio 18. Other fuel compositions at different compression ratio are also presented but all have higher fuel consumption values than the former. It is easily noted that diesel has more fuel consumption in its sole form than the blended form.

Table 3 Chosen input parameter combinations

Experiment no.	Sample	Compression Ratio	Load
1	S1	17.5	3
2	S1	18	9
3	S1	17.5	6
4	S1	17	9
5	S1	17	3
6	S1	17	6
7	S1	17.5	9
8	S1	18	3
9	S1	18	6
10	S2	18	3
11	S2	18	9
12	S2	17	9
13	S2	18	6
14	S2	17.5	3
15	S2	17	6
16	S2	17	3
17	S2	17.5	6
18	S2	17.5	9
19	S3	17	6
20	S3	17	9
21	S3	17.5	9
22	S3	18	9
23	S3	17.5	6
24	S3	17.5	3
25	S3	18	3
26	S3	18	6
27	S3	17	3

3.2. *Brake thermal efficiency*

The Fig. 3 depicts about the brake thermal efficiency obtained at various compression ratios using different fuel blends. The value of η_{bt} is lower for diesel in its sole form at all the compression ratios. The blended compounds have produced a higher η_{bt} even at lower compression state. The sample 2 (containing 95% diesel with 3% linseed oil and 2% Leishman's solution) has produced higher η_{bt} at a compression ratio of 18. The sample 3 (containing 90% diesel with 5% linseed oil and 5% leishman's solution) have produced a good result consistently at all the compression stages, however the maximum is achieved by the sample 2.

Table 4 Output values corresponding to the input parameter combination

Experiment no.	SFC [kg/kWh]	η_{bt} [%]	η_{mech} [%]	η_{vol} [%]
1	0.79	10.26	21.58	80.86
2	0.33	24.37	49.23	78.98
3	0.48	16.79	35.8	80.39
4	0.39	20.9	45.69	79.11
5	0.78	10.37	19.15	80.62
6	0.49	16.4	34.37	80.08
7	0.36	22.69	47.2	79.9
8	0.66	12.23	23.26	80.19
9	0.42	19.25	35.88	79.54
10	0.52	16.2	26.37	77.72
11	0.29	29.13	56.61	77.35
12	0.3	27.8	56.93	77.39
13	0.38	22.55	46.32	77.65
14	0.6	14.24	30.03	78.25
15	0.38	22.57	44.76	78.01
16	0.59	14.33	27.25	78.09
17	0.39	21.91	45	78.18
18	0.31	27.41	55.56	77.4
19	0.38	22.57	47.76	78.01
20	0.3	27.8	56.93	77.39
21	0.31	27.41	55.56	77.4
22	0.31	27.41	55.56	77.4
23	0.39	21.91	45	78.18
24	0.6	14.24	30.03	78.25
25	0.6	14.24	30.03	78.25
26	0.39	21.91	45	78.18
27	0.59	14.33	27.25	78.09

3.3. *Mechanical efficiency*

The mechanical efficiency of the diesel engine is found to be higher for the blended fuels than diesel at all the compression stages. The Fig. 4 represents mechanical efficiency plotted against the load. From the plot, it is understandable that the η_{mech} is very high for the sample 3 at higher compression ratios. The sample 2 has also produced a comparable result as that of sample 3 at higher compression ratio. Hence, it is understood that the compression ratio increase will provide higher mechanical efficiency.

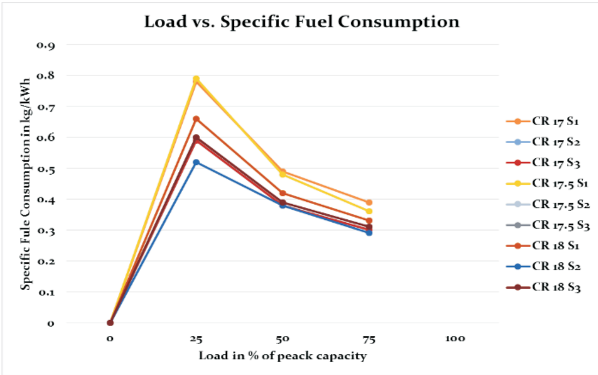

Figure 2 Response values of Specific Fuel Consumption at various loads for each sample

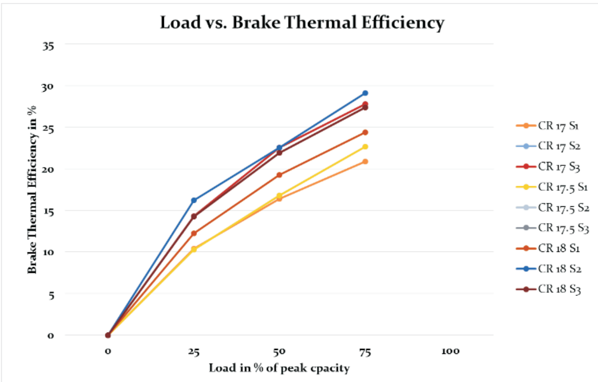

Figure 3 Response values of Brake Thermal Efficiency at various loads for each sample

3.4. *Volumetric efficiency*

The volumetric efficiency of the engine is found to be higher at the compression ratio 17.5 for diesel fuel. The figure 6 represents the volumetric efficiency plotted against load. The η_{vol} has to be high for any engine to produce a good combustion performance. The diesel blends however a lower η_{vol} than diesel has. The diesel fuel initially has an increasing effect on η_{vol} for improved compression ratio but tends to reduce at higher stages. Both the blends (sample 2 & 3) seem to produce an equal value of η_{vol} at each load and compression ratio combinations. There is only a slight deviation between the results and so the curves overlap one another in Fig. 5.

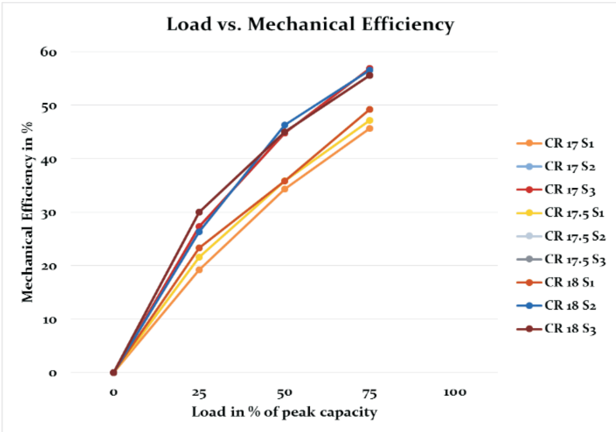

Figure 4 Response values of Mechanical Efficiency at various loads for each sample

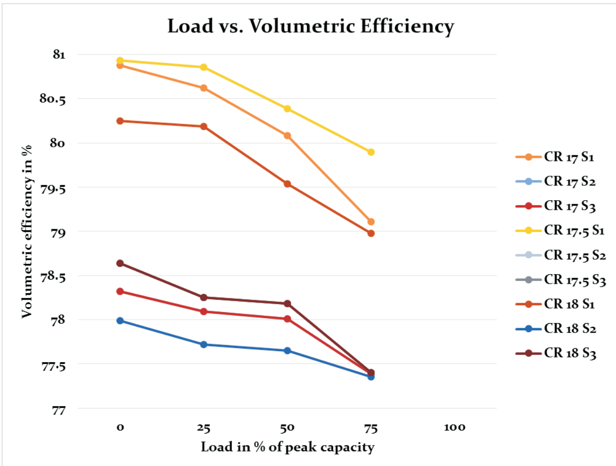

Figure 5 Response values of volumetric efficiency at various loads for each sample

4. Optimization using GRA

The Grey relational analysis is a method of measuring the degree of approximation among sequences according the Grey Relational Grade. The measured output values of the experiment like Mechanical, Volumetric, Brake thermal efficiencies and Specific Fuel Consumption are normalized in the range between 0 and 1.The optimization of the complicated multiple performance characteristics can be converted into optimization of single grey relational grade.
When the range of the sequence is large or the standard value is enormous, the function of factors is neglected. If the factors goal and direction are different, then the data must be pre–processed to a group of sequence called "grey relational generation". Data pre–processing is a process of transferring the original sequence to a comparable sequence.

Table 5 Grey Relation coefficient values for corresponding output

Exp. No.	GRC SFC	GRC η_{bt}	GRC η_{mech}	GRC η_{vol}	Total GRC	Grey Relation Grade	Rank
1	0.3333	0.3333	0.3483	1.0000	2.0149	0.50373	19
2	0.8621	0.6647	0.7104	0.4828	2.7200	0.67999	7
3	0.5682	0.4333	0.4720	0.7888	2.2623	0.56556	16
4	0.7143	0.5341	0.6269	0.5007	2.3761	0.59401	10
5	0.3378	0.3346	0.3333	0.8797	1.8855	0.47138	20
6	0.5556	0.4257	0.4557	0.6923	2.1293	0.53232	18
7	0.7813	0.5943	0.6600	0.6464	2.6820	0.67050	8
8	0.4032	0.3583	0.3594	0.7237	1.8446	0.46115	21
9	0.6579	0.4885	0.4730	0.5707	2.1901	0.54752	17
10	0.5208	0.4219	0.3820	0.3585	1.6832	0.42081	22
11	1.0000	1.0000	0.9833	0.3333	3.3167	0.82917	1
12	0.9615	0.8765	1.0000	0.3359	3.1739	0.79347	2
13	0.7353	0.5891	0.6403	0.3535	2.3182	0.57956	11
14	0.4464	0.3879	0.4125	0.4021	1.6489	0.41222	23
15	0.7353	0.5899	0.6082	0.3811	2.3145	0.57861	12
16	0.4545	0.3893	0.3889	0.3878	1.6206	0.40516	26
17	0.7143	0.5665	0.6129	0.3957	2.2894	0.57235	13
18	0.9259	0.8458	0.9324	0.3365	3.0406	0.76016	4
19	0.7353	0.5899	0.6732	0.3811	2.3795	0.59487	9
20	0.9615	0.8765	1.0000	0.3359	3.1739	0.79347	3
21	0.9259	0.8458	0.9324	0.3365	3.0406	0.76016	5
22	0.9259	0.8458	0.9324	0.3365	3.0406	0.76016	6
23	0.7143	0.5665	0.6129	0.3957	2.2894	0.57235	14
24	0.4464	0.3879	0.4125	0.4021	1.6489	0.41222	24
25	0.4464	0.3879	0.4125	0.4021	1.6489	0.41222	25
26	0.7143	0.5665	0.6129	0.3957	2.2894	0.57235	15
27	0.4545	0.3893	0.3889	0.3878	1.6206	0.40516	27

For this purpose the experimental results are normalized in the range between zero and one. The normalization can be done in various forms.

1. If the target value has a characteristic of "the larger–the–better":

$$x_i(k) = \frac{x_i(k) - min(x_i^0(k))}{max(x_i^0(k)) - min(x_i^0(k))}$$

2. If the target value has a characteristic of "smaller–the better":

$$x_i(k) = \frac{max(x_i(k)) - x_i^0(k)}{max(x_i^0(k)) - min(x_i^0(k))}$$

Following data pre–processing, a grey relational coefficient is calculated to express the relationship between the ideal and actual normalized experimental results. The grey relation coefficients of the present work is listed in the Tab. 5. After obtaining the grey relational coefficient, we normally take the average of the grey relational coefficient as the grey relational grade. The rank for various GRG is awarded on the basis of maximum to minimum value, as it depicts the order of desirability. The finalized average GRG value for the individual level of the input parameters is given in Tab. 6. The Fig. 6 depicts the selected level of each input for attaining best combustion performance based on the average Grey Relation Grade value.

Table 6 Optimized input parameter levels based on the GRG

	Sample	Compression Ratio	Load
Level 1	5.026	5.168	3.904
Level 2	**5.352**	5.229	5.115
Level 3	5.283	**5.263**	**6.641**

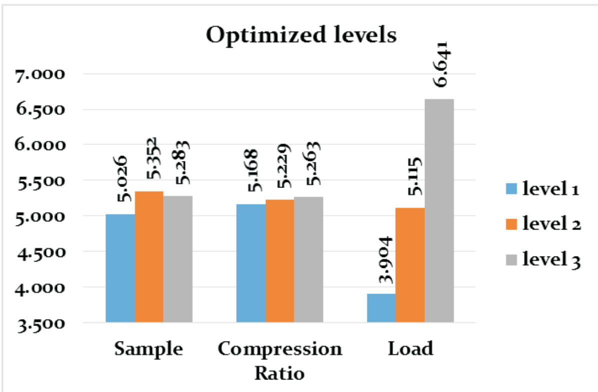

Figure 6 Optimized level values chosen based on the GRG

5. Conclusion

In Fig. 2–5, better combustion performance is explained clearly depicting about the contribution of various samples, loads and compression ratios individually. By the Grey Relation Analysis optimization procedure, the desirability of the combination of inputs for attaining the best possible output is also listed. From the average Grey Relation Grade value of each level it is concluded that sample 2 (containing 95%

diesel with 3% linseed oil and 2% Leishman's solution by volume) at a compression ratio of 18:1 will produce excellent performance in high load conditions. In future, several alternates of diesel additive can be investigated to attain higher combustion characteristics with reduced emission levels.

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