Diesel Engine Performance and emission characteristic enhancement by using Multi Criteria Decision Making Approach

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Abstract

The amount of concern arising from the emission problems causing environment and ecosystem are increasing exponentially which requires the automobile industry to find the optimum solution. This research deals with use of Jatropha oil as biodiesel to improve the emission characteristics, at same time the performance characteristics need to be improved. The diesel engine is optimized with different blends of Jatroha oil as biodiesel, compression ratio and load using L27 orthogonal array of full factorial design of experiment. The emission parameter are measured are HC, CO and CO_2 similarly performance parameters like Brake power, Brake thermal efficiency, specific fuel consumption and Volumetric efficiency are measured. The weightage is determined with the help of Entropy Method. The Multi criteria decision making is performed with the TOPSIS method.

Keywords: Entropy Method, TOPSIS Method, Diesel Engine Design of Experiment

1. Introduction

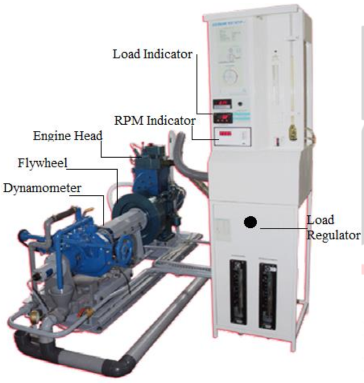
The Germen scientist Rudolph Diesel was pioneer in the development of fuel injector based combustion engine. Diesel and gasoline engines both were crucial in the development of automobile sector and transportation industry [1]. But, in comparison with gasoline engine, diesel engine offers the advantages of low fuel consumption, high durability and high thermal efficiency [2]. The market share of diesel powered passenger cars increasing sharply in world and every third car buyers choose diesel powered cars. Unfortunately, compared to the conventional catalyst equipped gasoline engine, diesel engine is notorious for being a source of particulate matter and NOx emissions.

The combustion efficiency of a diesel engine improves as injection pressure increases. This is due to the better atomization and mixing of fuel and air [3]. The development in the diesel engine was carried out to improve the engine performance and reducing the emissions due to stringent emission norms. One of the method of controlling NOx emissions is with the help of Exhaust gas circulation (EGR)[4]. As the number of holes in the injector increase, which in turn improve the diesel engine performance [5]. But, with the introduction of small percentage of Biodiesel not only improve the emission characteristics but there is slight reduction in engine performance [6].The combustion chamber geometry also play a vital role in improvements of engine performance.

In the paper, The Experimental Testing is performed on the single cylinder diesel engine with different blend of Jatropha oil biodiesel. Moreover the Load and compression ratio is varied to check the engine performance as well as emission characteristics of the diesel engine. The multi criteria decision male==king approach is used to find the optimum solution.

2. Experimental Setup

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to Hydraulic type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ−PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameter are provided for cooling water and calorimeter water flow measurement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Lab-view based Engine Performance Analysis software package "EnginesoftLV" is provided for on line performance evaluation. A computerized Diesel injection pressure measurement is optionally provided.



Fig, 1: VCR, Diesel Engine Test Setup.

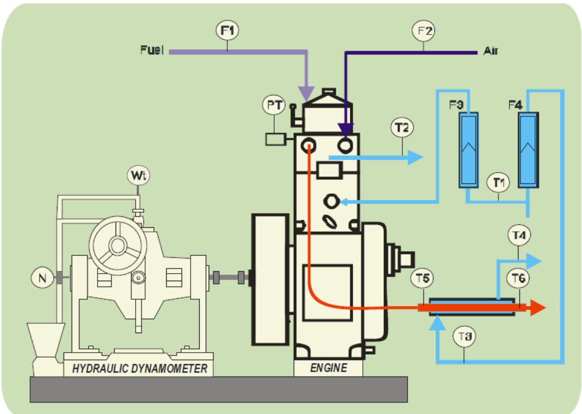


Fig. 2: Schematic diagram of Experimental setup.

3. Design of Experiment[7,8,9]

The experiments 1are performed on three different factors viz. Blend percentage of respective biodiesel with diesel, Load, and Compression ratio. Three levels are selected on the basis of experience and literature survey as described in Table 1 Full factorial design of experiment is utilized for 3 factor 3 level which gives 27 experiments as illustrated in Table No 2

Table No 1. Factors and Levels for WCC, Karanja and Jatropha Biodiesel

Factors	Levels		
	1	2	3
Blends % (A)	B10	B20	B30
Load (kg) (B)	3	6	9
Compression (C) Ratio	15:1	16:1	17

Table. 2 Design of experiment by Full Factorial Method

Expt No	Blend (A)	Load (B)	CR (C)
1	B10	3	15
2	B10	6	15
3	B10	9	15
4	B10	3	16
5	B10	6	16
6	B10	9	16
7	B10	3	17
8	B10	6	17
9	B10	9	17
10	B20	3	15
11	B20	6	15
12	B20	9	15
13	B20	3	16
14	B20	6	16
15	B20	9	16
16	B20	3	17
17	B20	6	17
18	B20	9	17
19	B30	3	15
20	B30	6	15
21	B30	9	15
22	B30	3	16
23	B30	6	16
24	B30	9	16
25	B30	3	17
26	B30	6	17
27	B30	9	17

The output parameters are measured with experimental setup which is described in section 3. The emissions responses measured are HC, CO2 and CO. Also performance responses like Break Power (BP), Break Thermal Efficiency (BTHE), Specific Fuel consumptions (SFC) and Volumetric efficiency are measured. The Measured output for Jatropha is shown Table No 3

Table 3. Emission and Performance Testing Results

Expt. No	HC	CO	CO_2	BP kW	BTH %	SFC	VE %
1	5	0.03	0.5	0.98	15.68	0.56	78.23
2	4	0.02	0.4	1.85	22.65	0.35	78.04
3	3	0.01	0.3	2.84	44.53	0.19	77.87
4	6	0.06	0.6	0.93	15.68	0.51	77.97
5	5	0.05	0.5	1.86	22.77	0.36	78.06
6	4	0.04	0.4	2.73	45.12	0.21	77.83
7	5	0.05	0.5	1.07	15.77	0.53	78.26
8	4	0.04	0.4	1.89	23.12	0.34	77.88
9	3	0.03	0.4	2.76	45.85	0.19	77.73
10	6	0.06	0.6	1.16	13.89	0.55	78.2
11	5	0.05	0.5	1.87	25.12	0.35	77.44
12	4	0.04	0.4	2.85	48.68	0.19	77.83
13	5	0.05	0.5	1.21	13.9	0.54	78.3
14	4	0.04	0.4	1.89	25.46	0.36	77.88
15	3	0.03	0.4	2.87	48.89	0.19	78.19
16	6	0.06	0.6	1.31	13.9	0.53	78.46
17	4	0.05	0.5	1.92	25.46	0.37	78.12
18	4	0.04	0.4	2.93	48.89	0.2	78.36
19	5	0.05	0.5	1.07	10.33	0.23	78.26
20	4	0.04	0.4	1.84	24.35	0.34	77.88
21	3	0.03	0.4	2.76	48.45	0.02	77.73
22	6	0.06	0.6	1.18	11.54	0.23	78.35
23	5	0.05	0.5	1.94	25.36	0.34	77.89
24	4	0.04	0.4	2.98	48.66	0.03	77.93
25	5	0.05	0.5	1.21	11.56	0.33	78.66
26	4	0.04	0.4	1.96	25.63	0.24	77.65
27	3	0.03	0.4	2.91	38.23	0.12	78.12

5.1. Entropy method[10,11,12]

Entropy method is objective weighting method which uses probability theory which measures uncertainty in output responses of each criteria to determine weightage of each criteria. The steps required in the entropy method are shown in Fig. 3

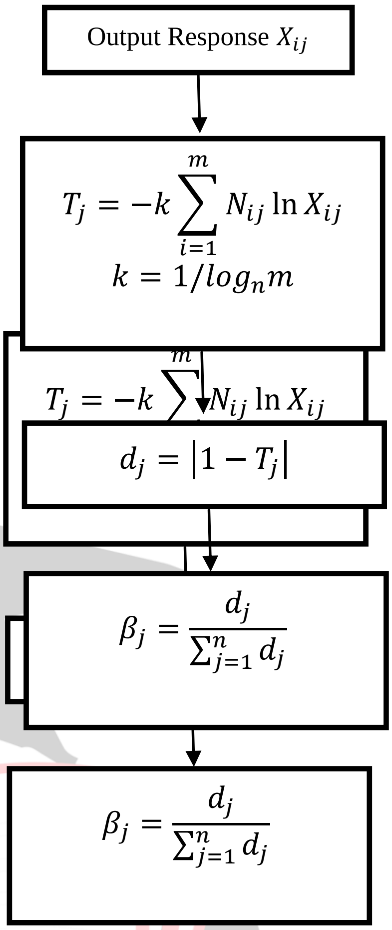


Fig.3 Flow chart of Entropy methods

Where i=Experiment Number; j=output response number ,

m=Total number of Experiments and n=total number of output response

β=weightage of corresponding jth response

The β values of weight responses each output responses are calculated with the help of flowchart explain in Fig. 3. The Table 4 shows the weightage of each response for respective biodiesel.

Table No 4 Weightage for Output response

HC	CO	CO_2	BP	BTH	SFC	VolE
0.1504	0.1451	0.1526	0.1402	0.1285	0.1266	0.1562

5.2. TOPSIS method[13,14,15]

TOPSIS is generally used to find the preference ranking of all alternate by using the output response of each criteria and to convert the multi-criteria system into a preferential index of single output response. The value which is close from the ideal solution, according to benefit and cost situation of all criteria will be used respectively. The TOPSIS index (Ci) is calculated as illustrated in Fig.4

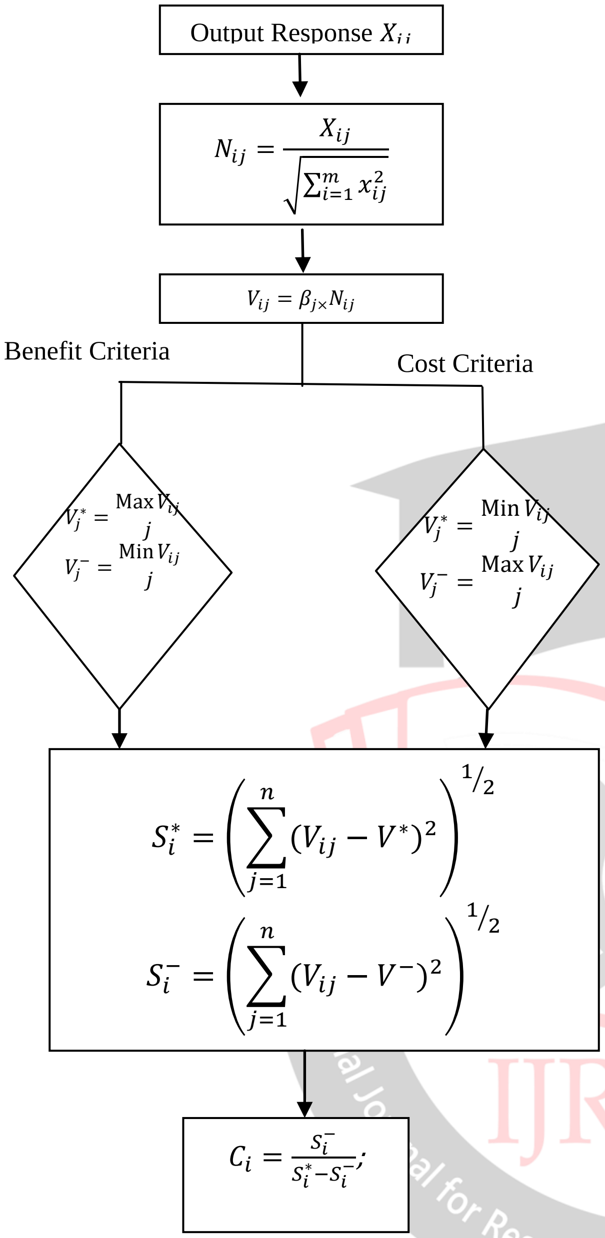


Fig.4 Flowchart for TOPSIS method

Where i=Experiment Number; j=output response number,

m=Total experiment Number and n=total number of output response

β=weightage of corresponding jth response which we have calculated by using entropy method for respective biodiesel. The first Step in TOPSIS method is to normalize the output so that each response will get converted in between 0 and 1. Then weighted normalization is carried out by multiplying with weights of respective output response which determined with help of Entropy Method. Then according to output response Criteria function, each response is analyzed so that the multi output response get converted into single output response, the descending order of output response gives ranking which helps to find the best optimum setting.

Table 4 shows the TOPSIS method analysis of L27 experiments which shows the experiment number 3 is highest rank .

Table 5 TOPSIS Coefficients and Ranking for Jatropha Biodiesel

Expt. No	Si*	Si'	C	Rank
1	0.0574	0.0215	0.2726	21
2	0.0361	0.0378	0.5110	11
3	**0.0126**	**0.0613**	**0.8296**	**1**
4	0.0658	0.0055	0.0772	26
5	0.0467	0.0237	0.3368	18
6	0.0254	0.0489	0.6586	9
7	0.0597	0.0122	0.1692	23
8	0.0396	0.0313	0.4420	14
9	0.0189	0.0541	0.7406	5
10	0.0667	0.0042	0.0588	27
11	0.0455	0.0250	0.3547	17
12	0.0243	0.0520	0.6814	7
13	0.0600	0.0120	0.1669	24
14	0.0395	0.0313	0.4424	13
15	0.0186	0.0560	0.7504	4
16	0.0653	0.0061	0.0851	25
17	0.0446	0.0271	0.3778	15
18	0.0246	0.0522	0.6798	8
19	0.0522	0.0258	0.3305	19
20	0.0393	0.0314	0.4442	12
21	0.0145	0.0617	0.8100	2
22	0.0581	0.0235	0.2880	20
23	0.0448	0.0260	0.3670	16
24	0.0211	0.0592	0.7372	6
25	0.0533	0.0200	0.2724	22
26	0.0346	0.0363	0.5121	10
27	0.0180	0.0548	0.7531	3

Conclusions

1. The weightage of found by using entropy method for Jatropha, gives volumetric efficiency a the highest weightage output
2. The entropy method uses the interrelation between the output responses hence the weightage obtained are reliable
3. Similarly TOPSIS method also gives optimum parameter setting for Jatropha is A1B3C1(Blend B10, Load 9 kg, and Compression ratio 15) ,

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