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Original Article

A Hybrid Multi-Criteria Decision-Making Technique for the Evaluation of TiO2 Nanoparticles as an Additive in Diesel-n-Butanol-Bombax ceiba Biodiesel Blends for Reduction of Pollution from IC Engines

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Abstract — *Due to population growth and rising demands for everyday conveniences, the energy demand has increased significantly, resulting in environmental pollution and depletion of non-renewable sources of energy. In this study, experiments were conducted to investigate the effects of Titanium dioxide (TiO2) nanoparticles on BCME and n-butanol (C4H9OH)diesel blends. Fuel samples containing n-butanol considerably impacted the blend's physicochemical qualities. The nanoparticles of TiO_2 were introduced at concentrations of 30, 60, and 90 ppm, respectively. Nano additives and n-butanol's oxygen content help in increasing engine performance and reducing engine emissions. The results of the tests were used in Crossover Multi-Criteria Decision Making (MCDM) methods to identify the best biodiesel blend. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a method for determining the optimal combination. Brake Thermal Efficiency (BTE), Hydrocarbon (HC), Oxides of Nitrogen (NOx), Carbon monoxide (CO) and Brake Specific Fuel Consumption (BSFC) are considered as the assessment criteria. For Brake power, B20Bu10T60 is ranked highest at 1.05, 4.16, and 5.2 kilowatts, while AHP-TOPSIS ranks it second at 2.1 and 3.12. A good substitute for diesel would be a mixture of B20Bu10T60 and B20Bu10T90 biodiesel. This study shows that 60ppm TiO2 nanoparticles are the ideal dose level for improving engine performance and reducing environmental pollutants.*

Keywords — *AHP, Butanol, BCME, Diesel, Emission, Engine, MCDM, Titanium Dioxide (TiO2), TOPSIS*.

I. INTRODUCTION

Diesel engines were widely used in the transport industry for public transit worldwide because of their increased durability and reliability. On the other hand, the transportation industry is responsible for 30 % of global emissions of greenhouse gases [1]. Automotive manufacturing organizations have already looked into different ways of cutting emissions from vehicles to meet possible mitigation standards. More importantly, renewable and other fuels such as Biodiesel and dimethyl ether (DME) have been shown to reduce NOx, GHGs and PM emissions [2]. Non-edible seeds from trees, including Pongamia, Mahua, castor, jatropha, etc., produce Biodiesel. It is possible to grow some of the non-edible oil plants in locations where less rainfall records[3][4]. Fossil energy shortage and environmental deterioration are two of the most pressing issues facing the globe today. Sustainable development, energy conservation and efficiency, and the protection of the environment have become increasingly important in the search for alternative fuels. Sakthivel et al. [5] used TOPSIS and VIKOR are MCDM techniques used to choose the blends. Before selecting the appropriate blend, it is necessary to consider a wide range of performance tests and emission factors. Aakula Swathi et al., [6], [7], [8], [9] used MCDM, the ideal nanoemulsion for an engine may be determined, and the best Nano biodiesel emulsion was obtained using two MCDM approaches, TOPSIS and VIKOR. Ors, I et al., [10] various engine speeds and full load conditions were used to test various fuel blends. Venu, H et al., [11] tested the effects of three distinct injection timings (IT), the original (ORG IT) of 23 deg, the advanced (ADV IT) of 27 deg, and the retarded (RET IT) of 19 deg bTDC. In

RET IT, nanoparticles had a minor effect on the BSFC (5.49 percent increase in 100 percent load). Aalam, C.S et al., [12] used a 1500 rpm engine for testing biodiesel, AONP mixed biodiesel. In an experimental investigation, Wu, Q et al., [13] found that the B10 suspension sample was stable and homogeneous, indicating that the dispersion stability of the sample was reasonably good. An experimental investigation by Shaafi, T et al. [14] found that the engine was stabilised by operating it for 15 minutes at each load. The efficiency of the two blends increases as the load increases. Jayasinghe, P et al., [15] has carried out an experimental investigation and Biofuels are made from biomass utilising biochemical, thermochemical and physical and chemical extraction techniques.

Vedaraman, N et al., [16] used palm biodiesel oil by transesterification, and then different blends (B20, B30, and B40) were prepared and tested in a normal diesel engine. According to the results of the engine tests, B20 is the best blend ratio for engine performance and emission characteristics. According to Banapurmath, methyl esters of Honge oil, Jatropha oil, and Sesame oil were used in a single-cylinder, four-stroke, DI and CI engine for testing. N.R et al., [17]. It has been shown that adding Jatropha biodiesel to mineral diesel has a positive influence on engine performance and emissions, and this has been tested experimentally by Paul, G et al. [18]. Biodiesel blends in IC engines can be selected using a hybrid MCDM technique, according to Sivaraja, C.M et al., [19]. Three approaches are used to determine the optimal mix: FAHP-VIKOR, FAHP-TOPSIS and FAHP-ELECTRE. In addition, the results of these MCDM approaches are compared with one another. CI engines powered by diesel, diesel and ethanol (20 percent blend) (E20), diesel and 20 percent jatropha blend (JB20), as well as diesel, 20 percent ethanol and 20 percent ethanol and jatropha blend (JBE20) have been studied and compared by Paul, G et al. [20]–[25].

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II. PROPOSED METHODOLOGY AND COMPUTATIONS

A. Proposed Methodology

To evaluate the criteria' weights using the AHP to identify the optimal blend among the various choices to get the rankings for all the blends, the MCDM techniques such as TOPSIS were used. The proposed methodology is shown in figure-1 is used to evaluate the ranks of all possible combinations for various loads.

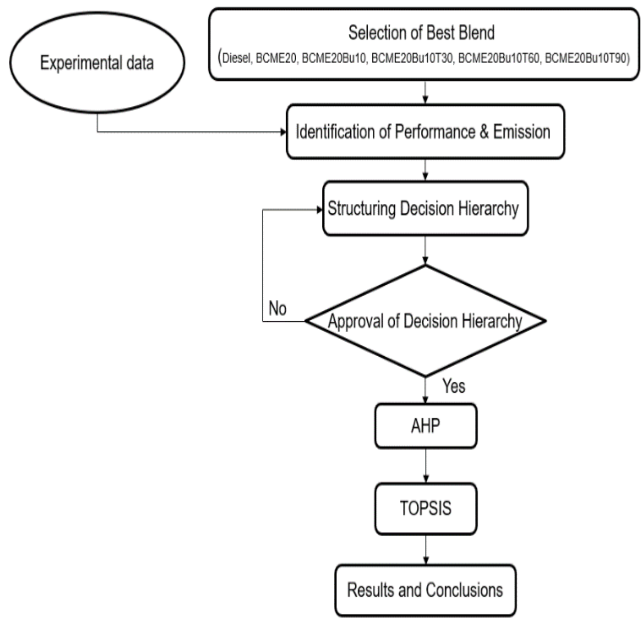

Fig. 1 Proposed Methodology

B. Analytical Hierarchical Process (AHP)

The criterion weights are calculated utilising this approach. It's a three-step process.

Step 1:

Figure 2 illustrates a hierarchical structure, "with the goal at the top, the criteria at the second level, and the options at the third level. Everything here is focused on finding weights for each criterion" [6].

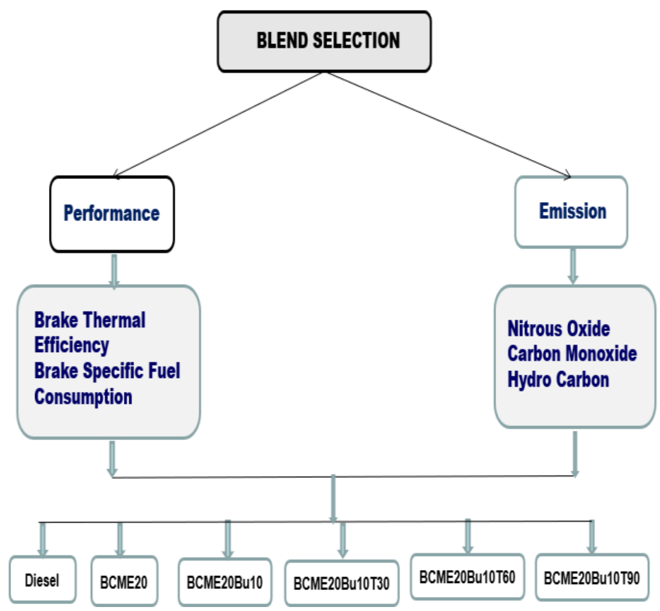

Fig. 2 Hierarchical decision making

Step 2:

This stage is all about creating a comparison matrix for two data sets. It defines how important each factor is concerning the overall aim. The relative relevance scale is used, and a pair-wise comparison matrix is created.

The number of criteria employed in the decision-making process determines the length of a pair-wise comparison matrix. It will be produced based on each item's importance or relative relevance in the matrix. Table 1 shows the results. Rows are separated into columns by the first element in each column so that all the items in a pair-wise comparison matrix's column may be found.

To normalise the pair-wise comparison matrix, each criterion must have a single value for each column of the pair-wise comparison matrix. Each column will have a single value. The sum of the individual entries in each column of a pair-wise comparison matrix divides each column into equal parts. By doing this for each of the other columns, we can create a normalised pair-wise comparison matrix, as shown in Table 2.

Step 3:

Table 1 contains a pair-wise comparison matrix that has not been normalised. The column elements should be multiplied by the criteria weight from Table 2 to verify the validity of the weights obtained. Table 3 displays the matrix of consistency.

The weighted total is then calculated by summarizing all the values in each row. For the ratio to be calculated, the weighted sum for each row must be divided by the criteria weight.

The average of these values is used to determine lambda max. The next step is to compute the consistency index.

λ = Weighted Sum Value / Criteria Weight (1)

Table 4 shows the outcome from using equation (1).

Consistency index (C.I) = (λmax-n)/(n-1) (2)

CR = C.I/R.C.I (3)

The Random Consistency Index (RCI) measures the randomness of a pair-wise matrices' degree of congruence. Table-5 shows a random index table with up to 10 criteria. It is then determined that a consistency ratio smaller than 0.1. The weights assigned to the various criteria are accurate.

TOPSIS Method

To choose the optimal blend from CO %, HCO, NOx PPM, BTE and BSfc (Kg/KWh), The following is a step-by-step process to the TOPSIS approach.

Step 1: Normalization of the evaluation matrix:

The normalised values of the alternatives Xij, as indicated in Table 7, are used to calculate alternative j's numerical score on criterion i. The following is the definition of the normalised value Xij:

$$\overline{X_{ij}} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n}(X_{ij})^2}}, \ i = 1,2,\ldots,m; \ j = 1,2,\ldots,n. \quad (4)$$

Table 8 shows the normalised decision matrix resulting from equation (4).

Step 2: The weighted normalised decision matrix is constructed:

By multiplying Xij by the weight Wj (as shown in Table 6), we can arrive at the weighted normalised decision matrix.

$$V_{ij} = \bar{X}_{ij} \times W_j \quad (5)$$

Following equation (5), a normalised weighted decision matrix is displayed in Table 9.

Step 3: A method for identifying the ideal solutions, both negative and positive: Vi+ represents the perfect solution. The minus signs Vi- denote the option that is the least desirable.

Vi+ & Vi- is shown in Table 10.

Step 4: Separation measure Calculation:

The n-criteria determines how far each alternative is from the ideals; Euclidean distance can be employed.

$$S_i^+ = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^+)^2} \quad (6)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^-)^2} \quad (7)$$

Using equations (6) & (7), S_i^+ & S_i^- is shown in Table 11.

Step 5: Determining how near a given solution is to the ideal one:

$$\text{Performance score } P_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (8)$$

According to Equation (8) Pi, Table 12 shows the result.

Step 6: Prioritizing:

The descending order of Pi can then be used to rate a group of alternatives

III. COMPUTATIONS

Prior to constructing a decision hierarchy, the various mixes and the criteria used to evaluate them are first identified. As a final step, the TOPSIS method is used to rank choices based on the evaluation criteria' observed values and relative weights.

For the finest blend, some guidelines followed are discussed below

The authors of this study utilized a literature review to develop a list of criteria for determining the best mix. Figure 1 illustrates the hierarchical structure of the criteria. IC engine experts and manufacturers use the decision-making process with a group decision-making method. The following is a list of the criteria that have been determined.

Brake thermal efficiency (BTE)
Brake-specific fuel consumption (BSFC)
Carbon monoxide (CO)
Hydrocarbon (HC)
Oxides of Nitrogen (NOx)

A. Brake thermal efficiency (BTE): Brake thermal efficiency is a metric for determining the engine's efficiency for the given input.

B. Brake-specific fuel consumption (BSFC): Using BSFC, the fuel efficiency of any prime mover that uses fuel to generate torque and power is measured. Internal combustion engines are often compared to shaft output using this method. The rate of fuel consumption is divided by the amount of power generated.

C. Carbon monoxide (CO): Incomplete combustion in an IC engine produces carbon monoxide. The complete combustion process produces carbon dioxide (CO_2). Carbon monoxide (CO) is formed due to a lack of oxygen in the combustion process.

D. Hydrocarbon (HC): In an engine, hydrocarbons that have not been burned are known as unburnt hydrocarbons (UHCs). In piston engines, some of the fuel-air mixture "hide" in the crevices formed by the grooves in the piston rings, which escapes from the engine during the exhaust stroke. The escaped HC is wasted from the engine and, on the other hand, causes severe air pollution

E. Oxides of Nitrogen (NOx): Human health and the natural environment are negatively impacted by nitrogen oxides. Oxides of nitrogen pollution's damaging effects don't always begin to take action immediately but rather after long-term exposure.

IV. AHP COMPUTATIONS

Evaluation criteria and alternative mixes create an effective decision hierarchal structure diagram. Objective, criteria, and options are all three levels of the choice model. However, these are located at the model's top, second, and bottom. As part of the AHP technique, it is important to compare each criterion against the others to determine their respective weights. Saaty's nine-point scale is used to evaluate each criterion to the others in the comparison matrix process. IC engine experts can determine individual criteria's relative importance via questionnaire design.

Table 1. Pair-wise comparison matrix

Criteria	**BTE**	**BSFC (Kg/(kW·h)**	**CO %**	**HC (PPM)**	**NOx (PPM)**
BTE	1	4	3	4	6
BSFC (Kg/(kW·h)	0.25	1	0.25	0.333	3
CO %	0.333	4	1	2	5
HC (PPM)	0.25	3	0.5	1	3
NOx (PPM)	0.166	0.333	0.2	0.333	1

Table 2. Normalised Pair-wise matrix

Criteria	**BTE**	**BSFC (Kg/(kW·h)**	**CO %**	**HC (PPM)**	**NOx (PPM)**
BTE	0.5003	0.3243	0.6061	0.5218	0.3333
BSFC (Kg/(kW·h)	0.1251	0.0811	0.0505	0.0434	0.1667
CO %	0.1666	0.3243	0.2020	0.2609	0.2778
HC (PPM)	0.1251	0.2432	0.1010	0.1304	0.1667
NOx (PPM)	0.0830	0.0270	0.0404	0.0434	0.0556

Table 3. Calculating the Consistency

Criteria	BTE	BSFC (Kg/(kW·h)	CO %	HC (PPM)	NOx (PPM)
BTE	0.4572	0.3734	0.7390	0.6131	0.2993
BSFC (Kg/(kW·h)	0.1143	0.0934	0.0616	0.0510	0.1497
CO %	0.1522	0.3734	0.2463	0.3066	0.2494
HC (PPM)	0.1143	0.2801	0.1232	0.1533	0.1497
NOx (PPM)	0.0759	0.0311	0.0493	0.0510	0.0499

Table 4. Calculation of λ

Criteria	Weighted Sum Value	Criteria Weights	λ
BTE	2.4820	0.4572	5.4293
BSFC (Kg/(kW·h)	0.4699	0.0934	5.0340
CO %	1.3280	0.2463	5.3912
HC (PPM)	0.8205	0.1533	5.3524
NOx (PPM)	0.2572	0.0499	5.1549

λmax = Average Value of λ = 5.27236074
From equation (2),
Consistency index (C.I) = 0.068090185
n – number of criteria = 5

Table 5. Random Consistency Index

No	1	2	3	4	5	6	7	8	9	10
RCI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

From equation (3),
Consistency Ratio = 0.060794808 < 0.10
TOPSIS Computations

Table 6 Beneficial and Non-beneficial criterion values calculated using AHP

Criteria	BTE	BSFC (Kg/(kW·h)	CO %	HC (PPM)	NOx (PPM)
Beneficial/Non-beneficial	Benf.	Non Benf.	Non Benf.	Benf.	Benf.
Weight(Wj)	0.4572	0.0934	0.2463	0.1533	0.0499

Table 7. Decision Matrix for alternative blends using AHP

Criteria Brake Power	BLENDS	BTE	BSFC (Kg/(kW·h)	CO %	H.C. (PPM)	NOx (PPM)
1.05	DIESEL	12.13691	0.7151	2.78	0.105	1.61
	BCME20	11.70755	0.76174	3.18	0.124	1.65
	BCME20Bu10	12.43691	0.6951	3.14	0.122	1.55
	BCME20Bu10T30	14.6771	0.63709	3.11	0.12	1.72
	BCME20Bu10T60	14.85629	0.62571	2.3	0.092	1.74
	BCME20Bu10T90	14.48893	0.63709	2.64	0.096	1.8
2.1	DIESEL	20.50887	0.49714	3.12	0.096	2.29
	BCME20	20.07008	0.51923	3.54	0.11	2.35
	BCME20Bu10	21.08868	0.48714	3.46	0.107	2.01
	BCME20Bu10T30	23.55079	0.47087	3.18	0.101	2.41
	BCME20Bu10T60	24.96965	0.435	2.6	0.081	2.53
	BCME20Bu10T90	24.7629	0.44766	2.75	0.0958	2.62
3.12	DIESEL	23.92199	0.36394	3.31	0.13	4.09
	BCME20	23.65403	0.39276	3.8	0.14	4.21
	BCME20Bu10	24.52199	0.34394	3.78	0.13	4.01
	BCME20Bu10T30	26.62106	0.32168	3.31	0.121	4.42
	BCME20Bu10T60	28.43176	0.29949	2.9	0.091	4.65
	BCME20Bu10T90	28.03161	0.30747	2.97	0.103	4.91
4.16	DIESEL	24.12941	0.37333	4.2	0.165	5.11
	BCME20	23.50366	0.408	4.4	0.173	5.21
	BCME20Bu10	24.62941	0.36533	4.7	0.168	5.05
	BCME20Bu10T30	29.40183	0.3157	3.94	0.162	5.8
	BCME20Bu10T60	31.21206	0.284	3.23	0.131	5.93
	BCME20Bu10T90	30.29504	0.2957	3.5	0.142	6.2
5.2	DIESEL	27.21088	0.354	5.51	0.2	6.21
	BCME20	26.59295	0.37404	6.59	0.218	6.41
	BCME20Bu10	29.71088	0.3364	6.51	0.214	6.01
	BCME20Bu10T30	31.02277	0.3	6.2	0.219	6.56
	BCME20Bu10T60	32.92867	0.26475	5.12	0.189	6.62
	BCME20Bu10T90	32.66596	0.27458	5.71	0.19	6.71

Table 8. Normalized matrix for various alternative blend using AHP

Criteria Brake Power	BLENDS	BTE	BSFC (Kg/(kW·h)	CO %	H.C. (PPM)	NOx (PPM)
1.05	DIESEL	0.3684	0.4290	0.3946	0.3877	0.3911
	BCME20	0.3554	0.4570	0.4514	0.4578	0.4009
	BCME20Bu10	0.3776	0.4170	0.4457	0.4504	0.3766
	BCME20Bu10T30	0.4456	0.3822	0.4414	0.4430	0.4179
	BCME20Bu10T60	0.4510	0.3754	0.3265	0.3397	0.4227
	BCME20Bu10T90	0.4398	0.3822	0.3747	0.3544	0.4373
2.1	DIESEL	0.3708	0.4255	0.4073	0.3962	0.3934
	BCME20	0.3628	0.4444	0.4622	0.4540	0.4037
	BCME20Bu10	0.3813	0.4169	0.4517	0.4416	0.3453
	BCME20Bu10T30	0.4258	0.4030	0.4152	0.4169	0.4140
	BCME20Bu10T60	0.4514	0.3723	0.3394	0.3343	0.4347
	BCME20Bu10T90	0.4477	0.3831	0.3590	0.3954	0.4501
3.12	DIESEL	0.3766	0.4373	0.4018	0.4409	0.3801
	BCME20	0.3723	0.4719	0.4613	0.4748	0.3912
	BCME20Bu10	0.3860	0.4132	0.4588	0.4409	0.3726
	BCME20Bu10T30	0.4190	0.3865	0.4018	0.4104	0.4107
	BCME20Bu10T60	0.4475	0.3598	0.3520	0.3086	0.4321
	BCME20Bu10T90	0.4412	0.3694	0.3605	0.3493	0.4563
4.16	DIESEL	0.3598	0.4440	0.4258	0.4275	0.3747
	BCME20	0.3505	0.4852	0.4461	0.4483	0.3820
	BCME20Bu10	0.3672	0.4345	0.4765	0.4353	0.3703
	BCME20Bu10T30	0.4384	0.3754	0.3994	0.4198	0.4253
	BCME20Bu10T60	0.4654	0.3377	0.3275	0.3394	0.4348
	BCME20Bu10T90	0.4517	0.3517	0.3548	0.3679	0.4546
5.2	DIESEL	0.3688	0.4518	0.3772	0.3975	0.3946
	BCME20	0.3604	0.4774	0.4511	0.4333	0.4073
	BCME20Bu10	0.4027	0.4294	0.4456	0.4254	0.3819
	BCME20Bu10T30	0.4205	0.3829	0.4244	0.4353	0.4169
	BCME20Bu10T60	0.4463	0.3379	0.3505	0.3757	0.4207
	BCME20Bu10T90	0.4427	0.3505	0.3909	0.3777	0.4264

Table 9. Weighted Normalized matrix for various alternative blends using AHP

Criteria Brake Power	BLENDS	BTE	BSFC (Kg/(kW·h)	CO %	HC (PPM)	NOx (PPM)
1.05	DIESEL	0.1684	0.0401	0.0972	0.0594	0.0195
	BCME20	0.1625	0.0427	0.1112	0.0702	0.0200
	BCME20Bu10	0.1726	0.0389	0.1098	0.0690	0.0188
	BCME20Bu10T30	0.2037	0.0357	0.1087	0.0679	0.0208
	BCME20Bu10T60	0.2062	0.0350	0.0804	0.0521	0.0211
	BCME20Bu10T90	0.2011	0.0357	0.0923	0.0543	0.0218
2.1	DIESEL	0.1695	0.0397	0.1003	0.0607	0.0196
	BCME20	0.1659	0.0415	0.1138	0.0696	0.0201
	BCME20Bu10	0.1743	0.0389	0.1113	0.0677	0.0172
	BCME20Bu10T30	0.1946	0.0376	0.1023	0.0639	0.0207
	BCME20Bu10T60	0.2064	0.0348	0.0836	0.0512	0.0217
	BCME20Bu10T90	0.2047	0.0358	0.0884	0.0606	0.0225
3.12	DIESEL	0.1721	0.0408	0.0990	0.0676	0.0190
	BCME20	0.1702	0.0441	0.1136	0.0728	0.0195
	BCME20Bu10	0.1765	0.0386	0.1130	0.0676	0.0186
	BCME20Bu10T30	0.1916	0.0361	0.0990	0.0629	0.0205
	BCME20Bu10T60	0.2046	0.0336	0.0867	0.0473	0.0216
	BCME20Bu10T90	0.2017	0.0345	0.0888	0.0535	0.0228
4.16	DIESEL	0.1645	0.0414	0.1049	0.0655	0.0187
	BCME20	0.1602	0.0453	0.1099	0.0687	0.0191
	BCME20Bu10	0.1679	0.0406	0.1174	0.0667	0.0185
	BCME20Bu10T30	0.2004	0.0350	0.0984	0.0643	0.0212
	BCME20Bu10T60	0.2128	0.0315	0.0807	0.0520	0.0217
	BCME20Bu10T90	0.2065	0.0328	0.0874	0.0564	0.0227
5.2	DIESEL	0.1686	0.0422	0.0929	0.0609	0.0197
	BCME20	0.1648	0.0446	0.1111	0.0664	0.0203
	BCME20Bu10	0.1841	0.0401	0.1098	0.0652	0.0191
	BCME20Bu10T30	0.1922	0.0357	0.1045	0.0667	0.0208
	BCME20Bu10T60	0.2040	0.0315	0.0863	0.0576	0.0210
	BCME20Bu10T90	0.2024	0.0327	0.0963	0.0579	0.0213

Table 10. Best value Vi* and worst value Vi- using AHP

Load Criteria	Vi*					Vi-				
	BP 1.05	BP 2.1	BP 3.12	BP 4.16	BP 5.2	BP 1.05	BP 2.1	BP 3.12	BP 4.16	BP 5.2
BTE	0.2062	0.2064	0.2046	0.2128	0.2040	0.1625	0.1659	0.1702	0.1602	0.1648
BSFC (Kg/(kW·h)	0.0350	0.0348	0.0336	0.0315	0.0315	0.0427	0.0415	0.0441	0.0453	0.0446
CO %	0.0804	0.0836	0.0867	0.0807	0.0863	0.1112	0.1138	0.1136	0.1174	0.1111
HC (PPM)	0.0702	0.0696	0.0728	0.0687	0.0667	0.0521	0.0512	0.0473	0.0520	0.0576
NOx (PPM)	0.0211	0.0217	0.0216	0.0217	0.0210	0.0188	0.0172	0.0186	0.0185	0.0191

Table 11. Euclidean distance from ideal best Si+ and from ideal worst Si- using AHP

BLENDS	Si*					Si-				
	BP 1.05	**BP 2.1**	**BP 3.12**	**BP 4.16**	**BP 5.2**	**BP 1.05**	**BP 2.1**	**BP 3.12**	**BP 4.16**	**BP 5.2**
DIESEL	0.0430	0.0418	0.0359	0.0551	0.0380	0.0171	0.0170	0.0253	0.0193	0.0191
BCME20	0.0540	0.0510	0.0449	0.0617	0.0482	0.0182	0.0186	0.0255	0.0183	0.0089
BCME20Bu10	0.0449	0.0428	0.0393	0.0588	0.0320	0.0202	0.0188	0.0219	0.0172	0.0213
BCME20Bu10T30	0.0285	0.0230	0.0206	0.0223	0.0221	0.0448	0.0339	0.0313	0.0473	0.0310
BCME20Bu10T60	0.0181	0.0183	0.0255	0.0167	0.0091	0.0540	0.0512	0.0450	0.0656	0.0483
BCME20Bu10T90	0.0205	0.0104	0.0196	0.0155	0.0135	0.0437	0.0479	0.0419	0.0569	0.0422

Table 12. Relative closeness to the ideal solution using TOPSIS with AHP

BLENDS	**Relative closeness to ideal solution and its ranking**									
	BP 1.05	**Rank**	**BP 2.1**	**Rank**	**BP 3.12**	**Rank**	**BP 4.16**	**Rank**	**BP 5.2**	**Rank**
DIESEL	0.2844	5	0.2891	5	0.4133	4	0.2591	4	0.3338	5
BCME20	0.2516	6	0.2670	6	0.3619	5	0.2286	5	0.1562	6
BCME20Bu10	0.3101	4	0.3054	4	0.3580	6	0.2268	6	0.3993	4
BCME20Bu10T30	0.6110	3	0.5961	3	0.6031	3	0.6795	3	0.5837	3
BCME20Bu10T60	0.7490	1	0.7361	2	0.6385	2	0.7974	1	0.8407	1
BCME20Bu10T90	0.6809	2	0.8215	1	0.6811	1	0.7863	2	0.7582	2

V. RESULTS AND DISCUSSION

The ranking order at BP 5.2 is considered to illustrate the result of the TOPSIS analysis. The ranking order by TOPSIS is based on closeness coefficient (BCME20Bu10T60 = 0.8407 <BCME20Bu10T90=0.7582 < BCME20Bu10T30 = 0.5837 <BCME20Bu10 = 0.3993 < Diesel=0.3338 < BCME20=01562). BCME20BuT60PPM was obtained as the best blend apart from diesel at BP 5.2. The mathematical model of AHP-TOPSIS was proposed and compared to select the best blend. In TOPSIS, the closeness coefficients of alternatives are not always closest to the ideal solution. A similar evaluation is carried out with Brake Power of 1.05, 2.1, 3.12 and 4.16. Thus, the final ranking based on AHP-TOPSIS technique is BCME20Bu10T60> BCME20Bu10T90>BCME20Bu10T30>BCME20Bu10>Diesel>BCME20). Overall, it is observed that BCME20Bu10T60 PPM is the suitable blend among all alternatives for different Brake Powers to minimize emissions to improve engine efficiency.

VI. CONCLUSION

Biodiesel use in I.C. engines is complicated by picking an optimal blend. Engine experts can use the proposed approach to identify the best blend to increase the engine's energy efficiency.

An AHP-TOPSIS decision-making process was utilized to find the optimal blend. TOPSIS and AHP are two different methods for determining the relative weights of assessment criteria.

AHP can eliminate the uncertainty involved in the decision makers' viewpoints for further investigation. In addition, a variety of MCDM methods, such as VIKOR, ELECTRE and PROMETHEE, can be used to select the ideal blend.

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