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Selecting Optimal Combination of Operating Parameters of VCR Diesel Engine Adopting AHP

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Abstract

Objective: To select the optimal combination of Variable compression ratio (VCR) diesel engine operating parameters using *Sesbania aculeate* biodiesel. **Method/Statistical Analysis:** The Analytical Hierarchy Process(AHP)approach is a mathematical approach used to find the optimal combination of VCR diesel engine operating parameters and the best blend of *Sesbania aculeata* biodiesel. **Findings:** It provides the alternatives and also the visualization of various criteria and their interrelations. The alternatives are ranked by measuring the criteria and their relative importance. The permanent concept helps for the better appreciation of criteria and considers the problem selection as it contains possible criteria components and their relative importance. It was found that the optimal combination of 100% load, 17.5 compression ratio and SAOME20 blend is the optimal combination of operating parameters of the VCR diesel engine. **Novelty/Improvement**: The best combination of operating parameters can be found systematically and logically using AHP.

Keywords: Matrix, Permanent Index, *Sesbania Aculeata* Biodiesel, VCR Engine, AHP

1. Introduction

It has been proven for many years that alternative fuels can fulfil the demand of energy as the petroleum based fuels are depleting day by day. In the present days, alternative fuels have become a very potential source of energy. Generally diesel engines have a high compression ratio.The fuel injected at high compression ratio (CR), the ignition take place before an adequate air-fuel mixture is formed and leads to heterogeneous combustion. The result shows, the formation NO_x because of the insufficient oxygen. When the compression ratio reduced, the temperature and pressure are reduced and leads in reduction of NO_x – soot emission. The engine best performance can be obtained by the optimal combination of operating parameters. The parameters like load, injection timing, compression ratio and injection pressure influence the engine performance.

In[1] the multi attribute decision making methods are proposed in conjunction with real time requirements. In[2–3] the different techniques were extensively applied to numerous diverse decision making problems.

In[4], the Analytical Hierarchy Process (AHP) was proposed. In[5], a number of functional characteristics make AHP a useful methodology. In[6], the vital characteristics of AHP included the ability to handle decision situations involving subjective judgements, multiple decision makers and the ability to provide measures of consistency of preferences. In[7], the AHP can efficiently deal with the objective or subjective attributes. In[8], AHP adopted for selection of materials for drinking water. In[9], AHP adapted to selection of manufacturing technologies. In[10], adapted AHP in modelling a team and in turn selection of a team leader.

The aim of this study is to select the optimum combination of operating parameters such as fuel blend, load and compression ratio to get the better performance of the diesel engine using AHP.

2. Experimental Setup

The experimental setup consists of a variable compression ratio diesel engine of Kirloskar make with 3.5 kW rated power at 1500 rpm rated speed. Necessary instruments

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have been installed to the engine to measure various parameters such as fuel consumption, air consumption, and speed. Also a 5 gas analyser is attached to the test rig for emission measurement. Standard operating procedure has been followed to conduct performance and emission test using diesel and blends of *S.aculeata* biodiesel are SAOME10 (10% *S.aculeata* biodiesel + 90% diesel), SAOME20 (20% *S.aculeata* biodiesel + 80% diesel), SAOME30 (30% *S.aculeata* biodiesel + 70% diesel) and SAOME40 (40% *S.aculeata* biodiesel + 60% diesel).

3. Methodology of AHP

The step wise procedure of AHP approach is given below:

Step 1: Attributes Matrix

The attributes matrix consist of alternatives, attributes and their relative importance[11]. In in this approach the blends of *S.aculeata* biodiesel, load and compression ratio are considered as alternatives. BSFC, BTE, NO_x, HC, CO, CO_2 and Smoke are the attributes. The decision matrix of given problem which having 60 experiments shown in Table 1.

Step 3: Relative Importance Values for Attributes

Using AHP[11], the decision makers analyses the attributes and assign the relative importance values (off diagonal element. The pair wise comparison matrix N, as shown in eq. (3) is formed with p_{ij} and p_{ji} where $p_{ij} = 1$ when i = j and $p_{ji} = 1/p_{ij}$.

$$N = \begin{bmatrix} 1 & p_{12} & p_{13}\cdot & \cdots & p_{1B} \\ p_{21} & 1 & p_{23} & \cdots & p_{2B} \\ p_{31} & \cdots & 1 & \cdots & p_{3B} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ p_{A1} & \cdots & p_{A2} & \cdots & 1 \end{bmatrix} \qquad (3)$$

Table 3 shows the scale for pair wise comparison.

The pair wise comparison matrix shown in this study shown in eq. (4), the judgment of relative importance values of attribute is obtained by the consistency check[11]. The consistency ratio should be less than 0.1 as per the decision making method. The consistency ratio was found for the Pair wise comparison matrix shown in eq. (4) is 0.052.

$$B_1 = \begin{bmatrix} Attribute & BTE & BSFC & NO_x & SMOKE & HC & CO & CO_2 \\ BTE & 1 & 3 & 2 & 2 & 2 & 4 & 3 \\ BSFC & 0.33 & 1 & 2 & 2 & 2 & 3 & 2 \\ NO_x & 0.50 & 0.50 & 1 & 3 & 2 & 4 & 3 \\ SMOKE & 0.50 & 0.50 & 0.33 & 1 & 2 & 2 & 2 \\ HC & 0.50 & 0.50 & 0.50 & 0.50 & 1 & 2 & 3 \\ CO & 0.25 & 0.33 & 0.25 & 0.50 & 0.50 & 1 & 2 \\ CO_2 & 0.33 & 0.50 & 0.33 & 0.50 & 0.50 & 0.50 & 1 \end{bmatrix} \qquad (4)$$

Step 2: Normalization of Decision Matrix

The Normalization process used for makes all the attributes values in to non- dimensional. The procedure of the normalization as given.

$d_{ij} = c_{ij}/\max_j(c_{ij})$; when the j^{th} attribute is found to be beneficial (1)

$d_{ij} = \min_j(c_{ij})/c_{ij}$; when the j^{th} attribute is found to be non beneficial. (2)

The decision matrix with normalized values shows in Table 2.

In this study, The BTE is beneficial and BSFC.NO_X, CO, HC, smoke and CO_2 are non beneficial.

Step 4: Matrix for Attributes of Alternatives

The attributes matrix of each alternative is formed with help of normalized values as diagonal and off diagonal elements is taken from eq. (4) and this matrix is represented as R in eq. (5).

$$R = \begin{bmatrix} d_1 & p_{12} & p_{13} & - & - & p_{1n} \\ p_{21} & d_2 & p_{23} & - & - & p_{2n} \\ p_{31} & p_{32} & d_3 & - & - & p_{3n} \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ p_{n1} & p_{n2} & p_{n3} & - & - & d_n \end{bmatrix} \qquad (5)$$

Where $[d_1, d_2, d_3 \ldots \ldots\ldots d_n]$ are the normalized values of attributes for the considered alternative.

Table 1. Engine output data

Exp No	Load (%)	CR	Blend	BSFC	BTE (%)	NO_x	HC	CO (%)	CO_2 (%)	Smoke
1	20	16.5	B10	1.85	9.77	3.68	10	12.5	16.1	4.96
2	20	16.5	B20	6.48	48.27	16.9	14.28	16.7	18.8	2.54
3	20	16.5	B30	4.63	11.11	8.72	4.28	10.42	11.25	5.55
4	20	16.5	B40	3.71	13.04	11.59	1.43	6.25	8.3	6.7
5	40	16.5	B10	3.71	6.6	5.11	12.65	20.3	20.7	6.04
6	40	16.5	B20	11.1	4.6	9.45	17.72	23.7	28.54	4.5
7	40	16.5	B30	8.63	4.76	12.77	7.14	16.9	16.54	7.06
8	40	16.5	B40	4.93	8.13	19.97	3.79	11.86	9.25	8.5
9	60	16.5	B10	7.63	3.8	2.6	4.9	22.7	23.9	15.6
10	60	16.5	B20	21.9	10.05	9.81	16.85	27.27	31.6	10.9
11	60	16.5	B30	17.07	6.6	16.67	7.86	16.7	17.13	16.7
12	60	16.5	B40	9.9	2.9	10.6	5.62	12.12	7.6	17.7
13	80	16.5	B10	7.36	7.7	3.43	10.1	15.47	24.7	22.6
14	80	16.5	B20	28.67	8.5	7.2	14	20.2	29.2	15
15	80	16.5	B30	20.35	5.7	10.1	7	13.09	21.09	26.5
16	80	16.5	B40	11.05	2.7	13.97	3	8.33	6.05	29.1
17	100	16.5	B10	7.4	2.78	3.08	9.91	12.01	23.59	15.63
18	100	16.5	B20	27.7	4.18	10.34	12.39	19.43	28.52	12.3
19	100	16.5	B30	12.09	1.12	9.13	6.6	12.07	16.1	20.11
20	100	16.5	B40	3.7	1.25	19.6	4.13	4.69	7.9	26.32
21	20	17.5	B10	0.8	2.4	4.61	20	4.9	14.03	5.3
22	20	17.5	B20	6.4	21.5	14.51	28	16.3	10.23	2.15
23	20	17.5	B30	3.2	53.3	9.98	17.6	11.4	14.41	10.87
24	20	17.5	B40	1.6	81.6	15.06	10.4	6.7	13.45	14.3
25	40	17.5	B10	1.02	5.2	5.53	17.42	12.5	18.08	6.19
26	40	17.5	B20	1.2	15.9	9.09	28.3	22.2	20.53	3.8
27	40	17.5	B30	6.12	11.08	12.89	17.42	6.9	17.78	11.5
28	40	17.5	B40	2.04	5.6	20.66	9.8	6.56	13.38	15.11
29	60	17.5	B10	3.45	9.2	3.23	15	15.1	21.06	14.6
30	60	17.5	B20	18.47	10.48	9.52	25.71	25.3	24.6	9.5
31	60	17.5	B30	12.01	6.3	7.64	16.43	15.1	18.08	18.91
32	60	17.5	B40	5.23	3.5	13.26	9.3	6.3	11.7	21.5
33	80	17.5	B10	2.62	2.13	3.84	15.03	10.3	22.25	21.22
34	80	17.5	B20	23.1	10.6	7.26	24.2	19.6	23.49	13.6
35	80	17.5	B30	13.8	7.31	10.38	16.03	6.21	18.15	27.01
36	80	17.5	B40	5.39	4.85	15.09	9.8	4.12	9.85	30.5
37	100	17.5	B10	4.61	3.52	3.45	1.32	9.37	21.72	14.96
38	100	17.5	B20	27.5	6.43	10.11	9.93	19.53	23.9	11.37
39	100	17.5	B30	15.07	3.62	9.21	4.43	7.03	16.9	20.7
40	100	17.5	B40	7.69	1.33	20	12.2	6.25	10.6	25.8
41	20	18.5	B10	0.7	24.58	5.87	5.84	12.5	6.41	6.75
42	20	18.5	B20	3.54	8.78	13.03	11.7	17.01	8.15	2.29
43	20	18.5	B30	2.83	62.2	9.6	15.2	4.5	9.81	10.75
44	20	18.5	B40	1.42	65.9	17.33	24.1	1.13	5.16	26.91
45	40	18.5	B10	3.44	12.8	6.32	3.75	12.7	13.38	7.41
46	40	18.5	B20	11.02	15.36	9.19	13.6	22.2	17.25	3.8
47	40	18.5	B30	6.89	9.4	11.9	13.7	6.9	15.08	11.4

Exp No	Load (%)	CR	Blend	BSFC	BTE (%)	NO_X	HC	CO (%)	CO_2 (%)	Smoke
48	40	18.5	B40	4.64	2.99	21.05	22.2	5.56	11.2	26.5
49	60	18.5	B10	2.47	5.39	4.27	2.39	15.2	19.41	14.8
50	60	18.5	B20	15.14	10.34	9.52	13.4	25.3	21.23	9.5
51	60	18.5	B30	8.7	6.28	11.6	11.8	7.5	15.6	18.18
52	60	18.5	B40	6.4	2.52	15.02	20.3	6.32	12.8	29.9
53	80	18.5	B10	5.75	4.5	4.5	3.3	10.3	18.75	20.9
54	80	18.5	B20	20.23	6.26	7.59	12	19.6	20.6	12.9
55	80	18.5	B30	11.63	3.16	10.12	11.17	19.3	16.05	25.9
56	80	18.5	B40	2.83	1.25	6.21	20.09	4.12	11.16	35.85
57	100	18.5	B10	10.41	5.03	4.13	17.6	2.01	18.69	15.08
58	100	18.5	B20	35.2	8.21	10.04	26.89	13.04	21.61	10.93
59	100	18.5	B30	22.5	3.58	9.41	15.96	20	15.3	19.55
60	100	18.5	B40	14.58	4.3	24.52	8.82	9.561	11.6	24.08

Table 2. Normalized values

Exp no.	Load (%)	CR	Blend	BSFC	BTE (%)	NO_X	HC	CO (%)	CO_2 (%)	Smoke
1	20	16.5	B10	0.3783	0.1198	0.7065	0.132	0.0909	0.3205	0.4335
2	20	16.5	B20	0.1080	0.5915	0.1538	0.0924	0.0681	0.2745	0.8465
3	20	16.5	B30	0.1512	0.1361	0.2981	0.3084	0.1090	0.4587	0.3874
4	20	16.5	B40	0.1887	0.1598	0.2243	0.9230	0.1818	0.6217	0.3209
5	40	16.5	B10	0.1887	0.0808	0.5088	0.1043	0.0559	0.2492	0.3559
6	40	16.5	B20	0.0630	0.0563	0.2751	0.0745	0.0479	0.1809	0.4778
7	40	16.5	B30	0.0811	0.0583	0.2036	0.1849	0.0672	0.3119	0.3045
8	40	16.5	B40	0.1419	0.0996	0.1301	0.3482	0.0958	0.5578	0.2529
9	60	16.5	B10	0.0917	0.0465	1	0.2693	0.0501	0.2159	0.1378
10	60	16.5	B20	0.0319	0.1231	0.2650	0.0783	0.0416	0.1633	0.1972
11	60	16.5	B30	0.0410	0.0809	0.1559	0.1679	0.0680	0.0301	0.1287
12	60	16.5	B40	0.0707	0.0355	0.2452	0.2348	0.0937	0.6789	0.1215
13	80	16.5	B10	0.0951	0.0943	0.7580	0.1306	0.0734	0.2089	0.0951
14	80	16.5	B20	0.0244	0.1041	0.3611	0.0942	0.05623	0.1767	0.1433
15	80	16.5	B30	0.0343	0.0698	0.2574	0.1886	0.0867	0.2447	0.0811
16	80	16.5	B40	0.0633	0.0330	0.1861	0.44	0.1363	0.8529	0.0738
17	100	16.5	B10	0.0945	0.0340	0.8441	0.1331	0.0945	0.2187	0.1375
18	100	16.5	B20	0.0252	0.0512	0.2514	0.1065	0.0584	0.1809	0.1747
19	100	16.5	B30	0.0578	0.0137	0.2847	0.2	0.0941	0.3204	0.1069
20	100	16.5	B40	0.1891	0.01532	0.1326	0.3196	0.2422	0.6531	0.0816
21	20	17.5	B10	0.875	0.0294	0.5639	0.066	0.2318	0.3677	0.4056
22	20	17.5	B20	0.0109	0.2635	0.1792	0.0471	0.0697	0.5043	1
23	20	17.5	B30	0.2187	0.6531	0.2605	0.075	0.0996	0.3580	0.1977
24	20	17.5	B40	0.4375	1	0.1726	0.1269	0.1695	0.3836	0.1503
25	40	17.5	B10	0.6862	0.0637	0.4701	0.0757	0.09088	0.2853	0.3473
26	40	17.5	B20	0.5833	0.1948	0.2860	0.0466	0.05177	0.2513	0.5657
27	40	17.5	B30	0.1143	0.1358	0.2017	0.0757	0.1646	0.2902	0.1869
28	40	17.5	B40	0.3431	0.0686	0.1258	0.1346	0.1731	0.3856	0.1423
29	60	17.5	B10	0.2028	0.1127	0.8049	0.088	0.0752	0.2450	0.1471
30	60	17.5	B20	0.037	0.1284	0.2731	0.0513	0.0449	0.2097	0.2263
31	60	17.5	B30	0.0582	0.0772	0.3403	0.0803	0.07523	0.2853	0.1136

Exp no.	Load (%)	CR	Blend	BSFC	BTE (%)	NO_X	HC	CO (%)	CO_2 (%)	Smoke
32	60	17.5	B40	0.1338	0.0428	0.1960	0.1419	0.1803	0.4410	0.1
33	80	17.5	B10	0.2671	0.0261	0.6771	0.0878	0.1103	0.2319	0.1013
34	80	17.5	B20	0.0303	0.1299	0.3581	0.0545	0.0579	0.2197	0.1581
35	80	17.5	B30	0.0507	0.0895	0.2504	0.0823	0.1829	0.2841	0.0796
36	80	17.5	B40	0.1298	0.0594	0.1723	0.1347	0.2757	0.5238	0.0705
37	100	17.5	B10	0.1518	0.0431	0.7536	1	0.1212	0.2375	0.1437
38	100	17.5	B20	0.0254	0.0787	0.2571	0.1329	0.0582	0.2159	0.1890
39	100	17.5	B30	0.0464	0.0443	0.2823	0.2979	0.1615	0.3053	0.1038
40	100	17.5	B40	0.0912	0.0162	0.13	0.1081	0.18172	0.4868	0.0833
41	20	18.5	B10	1	0.0301	0.4429	0.2260	0.0908	0.8049	0.3185
42	20	18.5	B20	0.1977	0.1075	0.1995	0.1128	0.0667	0.6331	0.9389
43	20	18.5	B30	0.2473	0.7622	0.2708	0.0868	0.2524	0.5259	0.2
44	20	18.5	B40	0.4929	0.8075	0.1500	0.0547	1	1	0.0798
45	40	18.5	B10	0.2034	0.1568	0.4113	0.352	0.0894	0.3856	0.2901
46	40	18.5	B20	0.0635	0.1882	0.2829	0.0970	0.0511	0.2991	0.5658
47	40	18.5	B30	0.1015	0.1151	0.2184	0.0963	0.1646	0.3421	0.1886
48	40	18.5	B40	0.1508	0.0366	0.1235	0.0594	0.6852	0.4607	0.0811
49	60	18.5	B10	0.2834	0.0660	0.6088	0.5523	0.0747	0.2658	0.1452
50	60	18.5	B20	0.0462	0.1267	0.2731	0.0985	0.0449	0.2430	0.2263
51	60	18.5	B30	0.0804	0.0769	0.2241	0.1118	0.1514	0.3307	0.1183
52	60	18.5	B40	0.1093	0.0308	0.1731	0.0650	0.1797	0.4031	0.0719
53	80	18.5	B10	0.1217	0.0551	0.5778	0.4	0.1102	0.2752	0.1029
54	80	18.5	B20	0.0346	0.0767	0.3425	0.11	0.0579	0.2505	0.1667
55	80	18.5	B30	0.0601	0.0387	0.2569	0.1181	0.0588	0.3215	0.0831
56	80	18.5	B40	0.2473	0.0153	0.4186	0.0657	0.2757	0.4623	0.0599
57	100	18.5	B10	0.0672	0.0616	0.6295	0.075	0.5652	0.2761	0.1426
58	100	18.5	B20	0.0199	0.1006	0.2589	0.04918	0.0871	0.2387	0.1967
59	100	18.5	B30	0.0311	0.0438	0.2763	0.0827	0.0568	0.3372	0.1099
60	100	18.5	B40	0.0480	0.0526	0.1060	0.1496	0.1189	0.4449	0.0893

Table 3. Pair wise comparison scale

Class description	Relative importance of attributes	
	p_{ij}	p_{ji}
Two attribute are equal importance	1	1
One attribute is moderately important than that of other	2	½
One attribute is strongly important than the other	3	1/3
One attribute is very strongly important than the other	4	¼
One attribute is exactly important than the other	5	1/5

Table 4. Permanent index (determinant) values and rank

Exp No.	Blend	CR	Load (%)	Determinant	Rank
30	20	17.5	100	48	1
18	40	16.5	60	47	2
10	20	16.5	100	46	3
59	40	18.5	80	45	4
55	30	18.5	100	45	5

Exp No.	Blend	CR	Load (%)	Determinant	Rank
14	30	16.5	80	45	6
58	40	18.5	60	45	7
38	40	17.5	60	45	8
11	30	16.5	20	45	9
15	30	16.5	100	44	10
34	30	17.5	80	44	11
31	30	17.5	20	44	12
54	30	18.5	80	44	13
50	20	18.5	100	43	14
60	40	18.5	100	43	15
35	30	17.5	100	43	16
52	30	18.5	40	43	17
19	40	16.5	80	42	18
51	30	18.5	20	42	19
40	40	17.5	100	41	20
6	20	16.5	20	41	21
27	20	17.5	40	40	22
7	20	16.5	40	40	23
47	20	18.5	40	39	24
32	30	17.5	40	39	25
39	40	17.5	80	38	26
28	20	17.5	60	37	27
13	30	16.5	60	37	28
33	30	17.5	60	36	29
5	10	16.5	100	36	30
36	40	17.5	20	36	31
17	40	16.5	40	34	32
12	30	16.5	40	34	33
46	20	18.5	20	34	34
56	40	18.5	20	34	35
29	20	17.5	80	33	36
53	30	18.5	60	33	37
8	20	16.5	60	32	38
48	20	18.5	60	31	39
20	40	16.5	100	31	40
9	20	16.5	80	30	41
2	10	16.5	40	30	42
3	10	16.5	60	30	43
25	10	17.5	100	30	44
45	10	18.5	100	29	45
26	20	17.5	20	29	46
16	40	16.5	20	28	47
23	10	17.5	60	28	48
49	20	18.5	80	28	49
1	10	16.5	20	27	50
57	40	18.5	40	27	51
22	10	17.5	40	23	52
42	10	18.5	40	23	53

Exp No.	Blend	CR	Load (%)	Determinant	Rank
21	10	17.5	20	23	54
43	10	18.5	60	21	55
4	10	16.5	80	20	56
24	10	17.5	80	19	57
37	40	17.5	40	19	58
41	10	18.5	20	17	59
44	10	18.5	80	9	60

The alternative selection attribute matrix is shown in eq. (6).

$$R = \begin{bmatrix} d_{11} & 3 & 2 & 3 & 2 & 4 & 3 \\ 0.33 & d_{22} & 2 & 2 & 2 & 3 & 2 \\ 0.50 & 0.50 & d_{33} & 3 & 2 & 4 & 3 \\ 0.50 & 0.50 & 0.33 & d_{44} & 2 & 2 & 2 \\ 0.50 & 0.50 & 0.50 & 0.50 & d_{55} & 2 & 3 \\ 0.25 & 0.33 & 0.25 & 0.50 & 0.50 & d_{66} & 2 \\ 0.33 & 0.50 & 0.33 & 0.50 & 0.50 & 0.50 & d_{77} \end{bmatrix} \qquad (6)$$

Step 5: Permanent of Alternative Selection Attribute Matrix

The permanent function (Per C) or determinant also called index score and is calculated as follows.

A computer program was generated to simplify the Per(C) calculation

Step 6: Rank of Alternative

By using the step 5 calculates the index scores for all the 60 experiments and sorts either in ascending or descending order. The alternative with higher index score is ranked as higher from the alternatives.

The index score for alternative 1 is presented.

The alternative selection attribute matrix is given as (step 4),

$$\begin{aligned}
&Per(C) = \\
&\prod_{i=1}^{A} P_i + \sum_{i=1}^{A-1}\sum_{j=i+1}^{A} \cdots\cdots \sum_{A=t+1}^{A} (p_j\, p_j) P_k P_l P_m P_n P_o \ldots P_t P_m \\
&+ \sum_{i=1}^{A-2}\sum_{j=i+1}^{A-1}\sum_{k=j+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k + p_k\, p_k\, p_j) P_l P_m P_n P_o \ldots P_t P_M \\
&+ [\sum_{i=1}^{A-3}\sum_{j=i+1}^{A}\sum_{k=i+1}^{A-1}\sum_{l=i+2}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_j)(p_k\, p_k) P_m P_n P_o \ldots P_t P_M + \\
&\sum_{i=1}^{A-3}\sum_{j=i+1}^{A-1}\sum_{k=i+1}^{A}\sum_{l=j+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k\, p_l + p_l\, p_k\, p_k\, p_j) P_m P_n P_o \ldots P_t P_m] \\
&+ [\sum_{i=1}^{A-2}\sum_{j=i+1}^{A-1}\sum_{k=j+1}^{A}\sum_{l=1}^{A-1}\sum_{m=l+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k + p_k\, p_k\, p_j)(p_m\, p_m) P_n P_o \ldots P_t P_m \\
&+ \sum_{i=1}^{A-4}\sum_{j=i+1}^{A-1}\sum_{k=i+1}^{A}\sum_{l=i+1}^{A}\sum_{m=j+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k\, p_m\, p_m + p_m\, p_m\, p_k\, p_k\, p_j) P_n P_o \ldots P_t P_m] \\
&+ [\sum_{i=1}^{A-3}\sum_{j=i+1}^{A-1}\sum_{k=i+1}^{A}\sum_{l=j+1}^{A}\sum_{m=1}^{A-1}\sum_{n=m+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k\, p_l + p_l\, p_k\, p_k\, p_j)(p_m\, p_m) P_o \ldots P_t P_m \\
&+ \sum_{i=1}^{A-5}\sum_{j=i+1}^{A-1}\sum_{k=j+1}^{A}\sum_{l=1}^{A-2}\sum_{m=l+1}^{A-1}\sum_{n=m+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k + p_k\, p_k\, p_j)(p_m\, p_m\, p_n + p_h\, p_m\, p_m) P_o \ldots P_t P_m \\
&+ \sum_{i=1}^{A-5}\sum_{j=i+1}^{A}\sum_{k=i+1}^{A-3}\sum_{l=i+2}^{A}\sum_{m=k+1}^{A-1}\sum_{n=k+2}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_j)(p_k\, p_k)(p_m\, p_m) P_o \ldots P_t P_m \\
&+ \sum_{i=1}^{A-5}\sum_{j=i+1}^{A-1}\sum_{k=i+1}^{A}\sum_{l=i+1}^{A}\sum_{m=i+1}^{A}\sum_{n=j+1}^{A} \cdots \sum_{A=t+1}^{A} (p_j\, p_k\, p_k\, p_m\, p_m\, p_n + p_n\, p_m\, p_m\, p_k\, p_k\, p_j) P_o \ldots P_t P_m] \\
&+ \cdots\cdots \qquad (7)
\end{aligned}$$

$$R = \begin{bmatrix} 0.119 & 3 & 2 & 3 & 2 & 4 & 3 \\ 0.33 & 0.378 & 2 & 2 & 2 & 3 & 2 \\ 0.50 & 0.50 & 0.706 & 3 & 2 & 4 & 3 \\ 0.50 & 0.50 & 0.33 & 1 & 2 & 2 & 2 \\ 0.50 & 0.50 & 0.50 & 0.50 & 0.132 & 2 & 3 \\ 0.25 & 0.33 & 0.25 & 0.50 & 0.50 & 0.090 & 2 \\ 0.33 & 0.50 & 0.33 & 0.50 & 0.50 & 0.50 & 0.320 \end{bmatrix} \quad (8)$$

The calculated index score of experiment no.1 is 27 as shown in eq. (8). Likewise, the index scores for all given experiments are calculated and tabulated to rank them and are shown in Table 4.

4. Conclusion

The general procedure of the uniqueness of the decision making AHP approach by using the number of selection of qualitative and quantitative attributes the combination of optimal operating parameters of VCR diesel engine were found to be combination of 100% load, 17.5 compression ratio and SAOME20 blend.

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6. References

1. Geetha NK, Sekar P. An unprecedented multi attribute decision making using graph theory matrix approach. Int. j. eng. sci. technol. 2017; 21: 7–16. https://doi.org/10.1016/j.jestch.2017.12.011.
2. Geetha NK, Sekar P. Graph Theory Matrix Approach – A Qualitative Decision Making Too. Materials today Procedia. 2017; 4(8): 7741–7749. https://doi.org/10.1016/j.matpr.2017.07.109.
3. Geetha NK, Sekar P. Graph Theory Matrix Approach with Fuzzy Set Theory for Optimization of Operating Parameters on a Diesel Engine. Materials today Procedia. 2017; 4 (8): 7750–7759. https://doi.org/10.1016/j.matpr.2017.07.110.
4. The analytic hierarchy process [internet]. http://www.dii.unisi.it/~mocenni/Note_AHP.pdf. Date accessed: 1980.
5. Decision making in the manufacturing environment Using graph theory and fuzzy multiple attribute decision making [internet]. https://www.springer.com/gp/book/9781447143741. Date accessed: 2013.
6. Multi criteria decision making methods: A comparative study [internet]. https://www.springer.com/gp/book/9780792366072. Date accessed: 2000.
7. Cheung SO, Lam TL, Leung MY. An analytical hierarchy process based procurement selection method. Construction management and economics. 2001; 19(4): 427–437. https://doi.org/10.1080/014461901300132401.
8. Ahamad ZMN, Muhammad HFMF, Fairul AJ, Siti FZ. Fusion of fuzzy AHP in selecting material for drinking water bottle based on customer need. ARPN J. Eng. Appl. Sci. 2017; 12(14): 4243–4249.
9. Ernesto M, Adrian E. Manufacturing technology selection in the supply chain context by means of fuzzy.ARPN J. Eng. Appl. Sci. 2016; 11(1): 240–246.
10. Mazni O, Zahraa AA, Mazida A, Fauziah B, Azman Y, Haslina M, Norida MD. Team formation model of selecting team leader: an analytic hierarchy process (AHP) approach. ARPN J. Eng. Appl. Sci. 2015; 10(3): 1060–1067.
11. Geetha NK, BridjeshP.AHP Approach to Select Optimum Operating Parameters on Engine. Int. J. Pure Appl. Math. 2018; 119: 2291–2301.