International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

On the Selection of Optimum Blend of WPO – Combinatorial Mathematics Based Approach

Geetha.N.K[1], Sekar.P[2]

[1]*Assistant Professor, Department of Mathematics, Sri Krishna College of Engineering and Technology, Coimbatore, India 641008*
[2]*Dean, Faculty of Science and Humanities, SRM University, Chennai, India 600089.*

---***---

Abstract - *This paper presents the methodology of selection of optimum blend using combinatorial mathematics based approach from blends of waste plastic oil designated as WPO10, WPO20 and WPO30 based on the performance parameters like brake power, specific fuel consumption, mechanical efficiency, brake thermal and indicated thermal efficiency. It is found that WPO20 at 10kg load forms the optimum blend out of all the test fuels.*

Key Words: Waste plastic oil, Combinatorial mathematics based approach, CMBA, Blend

1. INTRODUCTION

With the rapid depletion of fossil fuels at a faster rate, an alternative fuel is needed to fulfill the needs of mankind. Out of the various alternative fuels, Waste Plastic Oil (WPO) is acclaimed to be a suitable alternative fuel as the properties of WPO are very close to diesel [1-3]. Researchers have put a lot of effort in production and characterization of WPO and its use as fuel on engines in neat and blend form [4-6].

The present study deals with the selection of optimum blend of WPO-Diesel. The statistical data for the present study if taken from the experimental results of Ankit et al. [7]. The blends of WPO are designated as WPO10 (10%WPO+ 90%Diesel), WPO20 (20%WPO+80%Diesel) and WPO30 (30%WPO+70%Diesel). The load on the engine is varied as 2kg, 4kg, 6kg, 8kg and 10kg. the results of experimental investigation are shown in Table1.

Table - 1: Experimental results

Exp No.	Blend	Load (kg)	BP (kW)	SFC Kg/kWh)	Mech Efficiency (%)	BTE (%)	ITE (%)
1	WPO 10	2	0.43	0.71	17.21	12	69.72
2	WPO 10	4	0.87	0.43	29.36	20.13	68.55
3	WPO 10	6	1.3	0.34	38.4	24.99	65.08
4	WPO 10	8	1.74	0.27	45.39	32.07	70.66
5	WPO 10	10	2.17	0.24	50.96	35.03	68.75
6	WPO 20	2	0.43	0.71	18.77	12.16	64.78
7	WPO 20	4	0.87	0.41	31.6	20.94	66.25
8	WPO 20	6	1.3	0.33	40.94	26.29	64.23
9	WPO 20	8	1.74	0.27	48.03	31.74	66.08
10	WPO 20	10	2.17	0.24	53.6	36.41	67.93
11	WPO 30	2	0.43	0.71	16.74	12.12	72.42
12	WPO 30	4	0.87	0.42	26.68	20.21	70.46
13	WPO 30	6	1.3	0.32	37.63	27.06	71.93
14	WPO 30	8	1.74	0.27	44.58	31.57	70.83
15	WPO 30	10	2.17	0.24	50.13	36.08	71.98

2. COMBINATORIAL MATHEMATICS BASED APPROACH

Combinatorial mathematics based approach (CMBA) is an integration of combinatorial mathematics matrix function and analytic hierarchy process and a [8]. The step wise procedure of CMBA is shown below:

Step 1: Decision matrix

Decision matrix is a collection of data for each experiment and is same as shown in Table1.

Step 2: Normalization

The size of the matrix is equal to the number of attributes considered. Normalization is to set the attribute data on same scale so that, comparisons can be made easier [9]. Let xij is the normalized value of yij for attribute i, then,

$$x_{ij} = \frac{y_{ij}}{\max_j (y_{ij})}$$; if jth attribute is beneficial

$$x_{ij} = \frac{\min_j (y_{ij})}{y_{ij}}$$; if, jth attribute is non-beneficial

The normalized values of attributes are shown in Table 2.

Table – 2: Normalized values of attributes

Exp No.	Blend	Load (kg)	BP (kW)	SFC Kg/kWh)	Mech Efficiency (%)	BTE (%)	ITE (%)
1	WPO 10	2	0.198	1.000	0.321	0.330	0.963
2	WPO 10	4	0.401	0.606	0.548	0.553	0.947
3	WPO 10	6	0.599	0.479	0.716	0.686	0.899
4	WPO 10	8	0.802	0.380	0.847	0.881	0.976
5	WPO 10	10	1.000	0.338	0.951	0.962	0.949
6	WPO 20	2	0.198	1.000	0.350	0.334	0.895
7	WPO 20	4	0.401	0.577	0.590	0.575	0.915
8	WPO 20	6	0.599	0.465	0.764	0.722	0.887
9	WPO 20	8	0.802	0.380	0.896	0.872	0.912
10	WPO 20	10	1.000	0.338	1.000	1.000	0.938
11	WPO 30	2	0.198	1.000	0.312	0.333	1.000
12	WPO 30	4	0.401	0.592	0.498	0.555	0.973
13	WPO 30	6	0.599	0.451	0.702	0.743	0.993
14	WPO 30	8	0.802	0.380	0.832	0.867	0.978
15	WPO 30	10	1.000	0.338	0.935	0.991	0.994

Step 3: Relative Importance

After analyzing the attributes, the relative importance of attributes is assigned. Table 3 shows the scale for pairwise comparison [10].

The geometric mean approach of AHP is used to determine the relative normalized weights of the attributes and the consistency check is carried out. It is required that the consistency ratio value of the relative importance of attributes should be less than 0.10 [11]. The consistency ratio in the present study is found to be 0.068. The consistency evaluation is shown in Table 4.

Step 4: Formation of alternate selection attribute matrix

The alternative selection matrix is formed by keeping the normalized values for attributes for the alternative as diagonal elements. The matrix is represented by, B.

$$B = \begin{bmatrix} R_1 & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & R_2 & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & R_3 & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & R_4 & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & R_5 \end{bmatrix} \quad (1)$$

Step 5: Permanent function

The permanent function used in Combinatorial mathematics characterizes the configuration of a system [12]. The characteristic permanent function for the standard matrix is shown in Eq. 2.

$$
\begin{aligned}
&Per(B) = \\
&\prod_{i=1}^{M} D_i + \sum_{i=1}^{M-1}\sum_{j=i+1}^{M} \dots\dots\dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{ji})D_kD_lD_mD_nD_o\dots.D_tD_m \\
&+\sum_{i=1}^{M-2}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M} \dots\dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{ki}+d_{ik}d_{kj}d_{ji})D_lD_mD_nD_o\dots.D_tD_M \\
&+[\sum_{i=1}^{M-3}\sum_{j=i+1}^{M}\sum_{k=i+1}^{M-1}\sum_{l=i+2}^{M} \dots\dots\dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{ji})(d_{kl}d_{lk})D_mD_nD_o\dots..D_tD_M + \\
&\sum_{i=1}^{M-3}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=j+1}^{M} \dots. \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{kl}d_{li}+d_{il}d_{lk}d_{kj}d_{ji})D_mD_nD_o\dots..D_tD_m] \\
&+[\sum_{i=1}^{M-2}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M}\sum_{l=1}^{M-1}\sum_{m=l+1}^{M} \dots\dots. \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{ki}+d_{ik}d_{kj}d_{ji})(d_{lm}d_{ml})D_nD_o\dots\dots D_tD_m \\
&+\sum_{i=1}^{M-4}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\sum_{m=j+1}^{M} \dots\dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{kl}d_{lm}d_{mi}+d_{im}d_{ml}d_{lk}d_{kj}d_{ji})D_nD_o\dots\dots D_tD_m] \\
&+[\sum_{i=1}^{M-3}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=j+1}^{M}\sum_{m=1}^{M-1}\sum_{n=m+1}^{M} \dots\dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{kl}d_{li}+d_{il}d_{lk}d_{kj}d_{ji})(d_{mn}d_{nm})D_o\dots\dots D_tD_m \\
&+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M}\sum_{l=1}^{M-2}\sum_{m=l+1}^{M-1}\sum_{n=m+1}^{M} \dots\dots. \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{ki}+d_{ik}d_{kj}d_{ji})(d_{lm}d_{mn}d_{nl}+d_{ln}d_{nm}d_{ml})D_o\dots\dots.D_tD_m \\
&+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M}\sum_{k=i+1}^{M-3}\sum_{l=i+2}^{M}\sum_{m=k+1}^{M-1}\sum_{n=k+2}^{M} \dots\dots. \sum_{M=t+1}^{M}(d_{ij}d_{ji})(d_{kl}d_{lk})(d_{mn}d_{nm})D_o\dots\dots.D_tD_m \\
&+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\sum_{m=i+1}^{M}\sum_{n=j+1}^{M} \dots\dots \sum_{M=t+1}^{M}(d_{ij}d_{jk}d_{kl}d_{lm}d_{mn}d_{ni}+d_{in}d_{nm}d_{ml}d_{lk}d_{kj}d_{ji})D_o\dots..D_tD_m] \\
&+\dots\dots\dots\dots\dots\dots
\end{aligned} \tag{2}
$$

Table – 3: Scale for pairwise comparison

Degree of importance	Definition
1	Equal
2	Intermediate between 1 and 3
3	Moderately preferable
4	Intermediate between 3 and 5
5	Strongly preferable
6	Intermediate between 5 and 7
7	Very strongly preferable
8	Intermediate between 7 and 9
9	Extremely strongly preferable
½, 1/3, ¼, 1/5, 1/6, 1/7, 1/8, 1/9	Reciprocals of 2, 3, 4, 5, 6, 7, 8 and 9

Table – 4: Consistency evaluation

	BP (kW)	SFC Kg/kWh)	Mech Efficiency (%)	BTE (%)	ITE (%)	Total	Average	Consistency Measure
BP (kW)	0.353	0.444	0.343	0.235	0.222	1.598	0.320	5.259
SFC (Kg/kWh)	0.118	0.222	0.343	0.235	0.222	1.140	0.228	5.435
Mech Efficiency (%)	0.176	0.111	0.171	0.353	0.222	1.034	0.207	5.360
BTE (%)	0.176	0.111	0.057	0.118	0.222	0.685	0.137	5.090
ITE (%)	0.176	0.111	0.086	0.059	0.111	0.543	0.109	5.102
							CI	0.062
							RI	0.91
							CR	0.068

Step 6: Rank of alternatives

The rank of alternatives is based on the permanent function value of the alternative selection matrix, also called as Index score. The alternative for which the value of Index score is highest is the best choice for the considered decision making problem. The Index score for all alternatives is sorted and ranked as shown in Table 5.

Table – 5: Index score for alternatives

Exp No.	Blend	Load (kg)	Index score	Rank
10	WPO 20	10	141.4409	1
15	WPO 30	10	141.2131	2
5	WPO 10	10	139.798	3
4	WPO 10	8	132.5319	4
14	WPO 30	8	131.9812	5
9	WPO 20	8	131.8858	6
13	WPO 30	6	123.9184	7
8	WPO 20	6	122.7776	8
3	WPO 10	6	121.7662	9
2	WPO 10	4	115.2242	10
7	WPO 20	4	115.138	11
12	WPO 30	4	114.5299	12
11	WPO 30	2	111.311	13
1	WPO 10	2	110.7055	14
6	WPO 20	2	110.0223	15

3. CONCLUSION

The proposed CMBA is adapted to select optimum blend of waste plastic oil. The computation used is comparatively simple compared to other multi attribute decision making methods. The measures of the attributes and their relative importance are used together to rank the alternatives. Hence, it provides a better evaluation. The use of permanent concept characterizes the considered approach as it contains all possible structural components of the attributes and their relative importance hence, no information is lost. This method can deal with problems considering both qualitative and quantitative attributes. The uniqueness of CMBA is that it offers a general procedure that can be applicable to diverse selection problems that incorporates vagueness and a number of selection attributes. The approach is logical, simple and convenient to implement.

NOMENCLATURE

BP: Brake power
SFC: Specific fuel consumption
BTE: Brake thermal efficiency
ITE: Indicated thermal efficiency
CMBA: Combinatorial mathematics based approach
WPO: Waste plastic oil
WPO10: 10%WPO+90%Diesel
WPO20: 20%WPO+80%Diesel
WPO30: 30%WPO+70%Diesel

REFERENCES

[1] Jindal. S, Nandwana. BP, Rathore. NS, Vashistha. V, Experimental investigations of the effect of compression ratio and injection pressure in a direct injection diesel engine running on jatropha methyl ester, Applied thermal engineering, 2010; 30; 442-448.

[2] Paul Daniel M, Vijay Kumar K, Durga Prasad B, Ravi Kumar P, Performance and emission characteristics of diesel engine operated on plastic Pyrolysis oil with exhaust gas recirculation, International journal of ambient energy, 2017; 38(3); 295-299.

[3] Damodharan D, Sathiyagnanam AP, Rana D, Rajesh Kumar B, Saravanan S, Extraction and characterization of waste plastic oil with the effect of n-Butanol addition on the performance and emissions of a DI diesel engine

fueled with WPO diesel blends, Energy conversion and management, 2017; 131; 117-126.

[4] Devraj J, Robinson Y, Ganapathi P, Experimental investigation of performance emission and combustion characteristics of waste plastic Pyrolysis oil blended with di ethyl ether used as fuel for diesel engine, Energy, 2015; 85; 304-309.

[5] Rajan kumar, Mishra MK, Singh SK, Arbind Kumar, Experimental evaluation of waste plastic oil and its blend on a single cylinder diesel engine, Journal of mechanical science and technology, 2016; 30(10); 4781-4798.

[6] Mani M, Nagarajan G, Sampath S, An experimental investigation on a DI diesel engine using waste plastic oil with exhaust gas recirculation, Fuel, 2010; 89; 1826-1832.

[7] Ankit Jani, Tushar Patel, Gaurav Rathod, Effect of Varying Load on Performance and Emission of CI Engine Using WPO Diesel Blend, IOSR Journal of Mechanical and Civil Engineering, 12 (2), PP 37-44, 2015.

[8] R. Venkata Rao, Decision making in the manufacturing environment using graph theory and fuzzy multiple attribute decision making methods, Volume 1, Newyork: Springer, 2007.

[9] R.V. Rao, F. Bleicher, D. Singh, V. Kalyankar, "Selecting environmentally conscious manufacturing program using combinatorial mathematics approach," International conference on engineering project and production management (EPPM 2011), singapore, Sep 20-21, 2011.

[10] T.L. Saaty, The analytic hierarchy process, Mc graw hill, 1980.

[11] E. Triantaphyllov, S.H. Mann, "An evaluation of the eigen value approach for determining the membership values in fuzzy sets," Fuzztsets and systems, vol. 35, pp. 295-301, 1990.

[12] M. Marcus, Minc, "Permanents," American mathematics monthly, vol. 72, pp. 571-591, 1965.