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Optimal Combination of Operating Parameters – Simple Additive Weighting Method

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Abstract

Selection of optimal combination of operating parameters is the success factor to obtain the best performance out of an engine. This paper considers a real application of Simple additive weighting method.

Keywords: Multi criteria decision making; Simple additive weighting; Multi attribute decision making

Introduction

For evaluating, ranking and selecting the most appropriate alternative among alternatives, multi-criteria decision making models are selector models. There are two approaches to multi-criteria decision making. They are Multi attribute decision making and Multi objective decision making. Every multi-criteria decision making has its own characteristics and the methods can also be classified as deterministic, stochastic and fuzzy methods [7]. The multi-criteria decision making plays an important role in solving complicated problems. It provides a step by step procedure for which a consensus decision can be made by a group of decision makers. Various multi-criteria decision making techniques used by decision makers and researchers are SAW, AHP, TOPSIS, PROMETHE, ANN, Fuzzy, GTA, etc.,

The methods of SAW and Fuzzy SAW are used for weight determinations and preferences. Churchman et al [2] used the SAW method in Portfolio selection problem. Afshari et al [1] applied SAW approach to solve Personnel selection problem. In their paper, data were collected by the opinion of experts using questionnaire in telecommunications companies. A scale of 1 to 5 was used to select best among five personnel.

Simple additive weighting method (SAW):

It was proposed by Fishburn [3] to analyze the additive utilities. In this method, each attribute is given a weight and the sum of all weights must be equal to 1. Each alternative is assessed with regard to every attribute [6,8]. The overall or composite performance score of an alternative is given by equation 1.

$$P_i = \sum_{j=1}^{m} W_j m_{ij} \qquad \text{--------} (1)$$

Where, m_{ij} represents the normalized value of the attributes. The alternative with the highest value of P_i is considered as the best alternative [4].

The steps involved in simple additive weighting method are [5]:

1. Construct a pair-wise comparison matrix for the criteria
2. Assign a score to show how much more important the criteria is
3. Obtain the normalized matrix from the comparison matrix

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4. The performance score of the alternatives is calculated using the eq. (1)

Application of simple additive weighting method:

Decision matrix in MADM method has four main parts, namely: 1. Alternatives, 2. Attributes, 3. Weight or relative importance of each attribute, 4. Measures of performance of alternatives w.r.t the attributes [8]. The decision table (decision matrix) shown in Table 1 comprises of alternatives, A_i (i=1,2,3,…..N), attributes, B_j (j=1,2,3,……M), weights of attributes, w_j (j=1,2,3,….. M) and the measures of performance of alternatives, m_{ij} (i=1,2,….N, j=1,2,….M). the elements of the decision matrix should be normalized to the same units.

Alternatives / Attributes	B_2 (w_2)	B_3 (w_3)	- - - - B_m (- - - - w_m)	B_1 (w_1)
A_1	m_{12}	m_{13}	- - - - m_{1m}	m_{11}
A_2	m_{22}	m_{23}	- - - - m_{2m}	m_{21}
A_3	m_{32}	m_{33}	- - - - m_{3m}	m_{31}
-	-	-	- - - - -	-
-	-	-	- - - - -	-
A_n	m_{n2}	m_{n3}	- - - - m_{nm}	m_{n1}

Table. 1: Decision table in MADM methods

Application of Simple additive weighting method

Experimental Methods

The engine used is a four stroke single cylinder, vertical, water cooled, natural aspirated, direct injection diesel engine. The specifications of the engine are given in table 2.

Component	Specification
Make	Kirloskar Engines Ltd, Pune
Type of engine	Four Stroke Single Cylinder Water Cooled Engine
Bore and Stroke	87.5 mm & 110 mm
Compression ratio	17.5 : 1
BHP and rpm	4.4kW & 1500 rpm
Fuel injection pressure	200 N/mm^2
Fuel injection timing	23^0 BTDC
Dynamometer	Eddy Current Dynamometer

Table.2.Specifications of engine test rig.

A pressure transducer is used to monitor the injection pressure. The engine apparatus was interfaced with an emission measurement device AVL Digas 444 a five gas analyser, and also the setup is provided with necessary instruments for measuring combustion pressure and crank angle. These signals are interfaced to the computer through engine indicator for P-V and P-Θ diagrams with AVL INDIMICRA 602 –T10602A software version V2.5. Atmospheric air enters the intake manifold of the engine through an air filter and an air box. An air flow sensor fitted with the air box gave the input for the air consumption to the data acquisition system. All the inputs such as air and fuel consumption, engine brake power, cylinder pressure and crank angle were recorded by the data acquisition system, which is stored in the computer and displayed in the monitor. A thermocouple in conjunction with a temperature indicator was connected at the exhaust pipe to measure the temperature of the exhaust gas. The smoke density of the exhaust was measured by the help of an AVL415 diesel smoke meter. A crank position sensor was connected to the output shaft to record the crank angle. The engine test rig is shown in figure 1 and the schematic diagram of experimental setup is given in Figure 2.

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Figure 1: Engine test rig

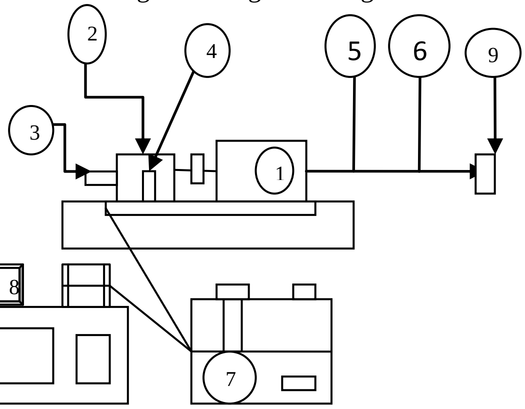

Figure 2. Schematic diagram of experimental setup

1. Engine 2. Dynamometer 3. Crank angle encoder 4. Load cell 5. Exhaust gas analyzer 6. Smoke meter 7. Control panel 8. Computer 9. Silencer

EXPERIMENTAL PROCEDURE

The engine used in this study was a direct injection single cylinder engine manufactured by Kirloskar. The engine was run at different compression ratios to evaluate the performance with emission charectaristics. Initially the engine was run on no load condition and its speed was maintained at a constant speed of 1500 rpm. The engine was tested at varying loads of 4.5 A, 9A, 13.5A and 18 A by means of an electrical dynamometer. For each loading conditions, the engine was run for at least 2 min after the data was collected. By changing the thickness of the cylinder head gasket the compression ratio can be changed to a certain limit. In order to vary the compression ratio of the engine in the present study, a thin copper spacer of 1 mm thick was inserted between the engine cylinder head and the cylinder block. With this various compression ratios of 16.4:1, 15.4:1, 14.5:1 and 13.7:1 are obtained by using 2 spacers apart from the standard compression ratio of 17.5:1.

The experimental results are shown in Table 3.

Exp No.	C.R	Load A	B.P kW	SFC kg/h kW	Bth Effic. %
1	16.4:1	4.5	1.10	0.548	15
2	16.4:1	9.4	2.27	0.358	22
3	16.4:1	13.9	3.30	0.311	27
4	16.4:1	18.2	4.00	0.323	25
5	15.4:1	4.3	1.08	0.552	15
6	15.4:1	9.3	2.26	0.357	22
7	15.4:1	13.7	3.26	0.316	25
8	15.4:1	18.1	4.18	0.364	23
9	14.5:1	4.3	1.10	0.582	14
10	14.5:1	9.3	2.26	0.358	22
11	14.5:1	13.7	3.27	0.395	21
12	14.5:1	18.1	3.98	0.438	18
13	13.7:1	4.3	1.08	0.635	14
14	13.7:1	9.3	2.23	0.378	21
15	13.7:1	13.6	3.16	0.436	18
16	13.7:1	18.0	3.02	0.583	16

The normalized values are shown in table 4.

Exp No.	Normalized Values of Criteria		
	B.P kW	SFC kg/h kW	Bth Effic. %
1	0.013	0.808	0.089
2	0.545	0.252	0.703

3	0.820	0.069	1.000
4	0.961	0.118	0.878
5	0.000	0.817	0.029
6	0.542	0.249	0.707
7	0.811	0.090	0.895
8	0.993	0.274	0.719
9	0.013	0.886	0.000
10	0.542	0.252	0.657
11	0.813	0.381	0.568
12	0.957	0.516	0.394
13	0.000	1.000	0.003
14	0.532	0.323	0.616
15	0.788	0.510	0.397
16	0.755	0.889	0.203

The weights of the criteria are shown in table 5.

B.P	B.S.F.C	B.T.E
0.6	0.2	0.2

The Performance scores for the experiments are evaluated using the eq. 1 and are tabulated in table 6.

Exp. No.	Performance Score	Rank
8	0.794	1
4	0.776	2
12	0.756	3
3	0.706	4
7	0.683	5
11	0.678	6
16	0.671	7
15	0.654	8
2	0.518	9
6	0.516	10
10	0.507	11
14	0.507	12
13	0.201	13
1	0.187	14
9	0.185	15
5	0.169	16

From the above table it is seen that the experiment no. 8 has highest value of performance score. Hence the combination of 15.4:1 compression ratio and 18 A load is the optimal combination of operating parameters for the best performance of the engine.

Conclusion

In this study, Simple additive weighting method is adapted to find the optimal combination of operating parameters of an engine.

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