EFFECT OF TBC COATED PISTON CROWN ON THE EMISSION OF TWO STROKE SI ENGINE

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Abstract

Conservation of energy and improvement of efficiency has always been the major area of concern for the automobile engineering. During the combustion stroke on an IC engine, a lot of heat is generated inside the combustion chamber, nearly thirty three percent of heat is absorbed by the cylinder walls, valves, piston, and etc. thirty three percent goes to the surrounding buy exhaust gases, the rest thirty four percent is used for the shaft work. By this study we aim to minimize the emission to the surrounding from the combustion chamber. The transfer of heat can be minimized by applying Thermal barrier coating on the various components of I.C. engine. A TBC is a ceramic material usually consisting of duplex structure the top coat and the bond coat. After studying various journals, we have found some TBC material candidate which could be used in our experiment. To find the optimal material, the method called as Simple Additive Weighted (SAW) method is used which is a non-traditional optimizing method under the category of Multiple Attribute Decision Making method.

Keywords: *Simple Additive Weighted Method, Multiple Attribute Decision Making, Thermal Barrier Coatings, Alumina, Weight, non-traditional methods*

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1. INTRODUCTION

Selection of material is a key factor for any industry. To solve this complex and important problem we must go for an analytical method rather than other initiative decisions. We had shortlisted a list of materials and their corresponding properties of utmost use. The demands of the properties of ideal material were different. Some should be high and some should be low. Now the question arises – Which material is best suited? There are many traditional optimizing methods like Linear Programming (LPP), Simplex method, Assignment method. But these cannot be applied because the variables were more than the requirement of the method. Simplex can be employed but the set of equations and its degree would be very high which would take years to calculate the solution. This is where the non-traditional optimizing methods come into the scenario. Here we have used Multiple Attribute Decision Making (MADM) method. Various methods come under this category like SAW/WSM, WPM, AHP, TOPSIS, and PEOMETHBE. We have used Simple Additive Weighting (SAW) method; one of the simplest methods of MADM.

The paper shows a real application of selection of material by using one of the MADM model. It is called Simple Additive Weighted method. Here, we have applied six attribute on eight alternatives that they are necessarily required for choosing the best suited material of TBC (Thermal Barrier Material) according to the rank.

2. METHODOLOGY

Simple Additive Weighting (SAW) is more oftenly used MADM method. It is also known as weighted linear combination method. This method is based on weighted average. A value is calculated for each alternative by multiplying the given value of each attribute with the weights of relative importance. And then the rank of the sum of scores of the attributes of each alternatives gives us the best among the given. Process of SAW consists of the following steps:

Step I:

1) Using the Saaty's 1-9 scale [2] form a pair-wise matrix of size (n*n) of the attributes as in Table 1. The table is used to compare each attribute with the other attributes individually.

Table 1: Saaty's 1-9 scale

	Numeric Rating	Reciprocal
Extreme importance	9	1/9
Very strong to extremely	8	1/8
Very strong importance	7	1/7
Strongly to very strong	6	1/6
Strong importance	5	1/5
Moderately to strong	4	1/4
Moderate importance	3	1/3
Equally to moderately	2	1/2
Equal importance	1	1

2) For each and every comparison, decide which of the two attribute has more importance, then designate a value to it. The less important attribute has score reciprocal of the more important attribute score. Compute the same for each comparison individually.
3) Weighted sum matrix is obtained by multiplication of the comparison matrix with the weight matrix.
4) Now divide all the cells of the weighted sum matrix by their individual weights.
5) Obtain the aggregate of this particular value to obtain α_{max}.
6) Determine the Consistency Index (CI):

$$CI = \frac{\alpha max - 1}{n-1}$$, where n is the matrix size.

7) Determine the Consistency Ratio (CR):

$$CR = \frac{CI}{RI}$$, where RI is the Random Consistency

8) If the CR does not exceed 0.01, it is acceptable.

The value of RI is taken from the table:

Table 2: Values of RI

Size of matrix	Random consistency
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Step II:

Formulate the decision matrix (m*n) and obtain the normalized decision matrix.

For maximization of the objective function:

$$N_{ij} = r_{ij} / r_j^* , \ i = 1,\dots m \text{ and } j = 1,\dots n$$

And for minimization of the objective function:

$$N_{ij} = r_j^{min} / r_{ij} , \ i = 1,\dots m \text{ and } j = 1,\dots n$$

Calculate each alternative, A_i by the formula:

$$A_i = \Sigma W_j x_{ij}$$

Where x_{ij} = value of the i[th] alternative w.r.t. the j[th] attribute, W_j = weighted attribute.

3. CALCULATION

By using six attribute given below we want to sort eight materials which can be used for coating the piston. These attribute are given in the Table 3:

Table 3: Attribute name

Attribute	Explanation
A1	Young's Modules
A2	Thermal diffusivity
A3	Thermal conductivity
A4	Heat capacity
A5	Poisson's number
A6	Density

The weights of the attribute can be calculated by using comparison matrix. Data was gathered by the research paper which attribute has more weightage than other attribute. It is given in Table 4 by using scale values of the range 1 – 3.

Table 4: Specifying the scale values

Intensity of importance	Definition
1	Equal importance
2	Strong importance
3	Extremely high importance

The Table 5 indicates the relative importance of the attributes in the columns compared to the attributes in the rows.

Table 5: Comparison Matrix

Attribute	A1	A2	A3	A4	A5	A6
A1	1.00	0.50	0.33	0.33	0.50	0.50
A2	2.00	1.00	0.50	0.50	1.00	0.50
A3	3.00	2.00	1.00	1.00	0.50	2.00
A4	3.00	2.00	1.00	1.00	2.00	1.00
A5	2.00	1.00	2.00	0.50	1.00	3.00
A6	2.00	2.00	0.50	1.00	0.33	1.00

Weights of attribute by comparison matrix:
1) Apply $(X)^{1/6}$ to each single cell of comparison matrix.
2) Product of each row.
3) Take the summation of product column obtained.
4) Weight, $W = \frac{product \ of \ each \ row}{summation \ of product \ coloumn}$

Attribute	A1	A2	A3	A4	A5	A6	∑	Weights
A1	1.00	0.8908	0.8312	0.8312	0.8908	0.8908	0.4883	0.07603
A2	1.1224	1.00	0.8908	0.8908	1.00	0.8908	0.7933	0.123522
A3	1.2009	1.1224	1.00	1.00	0.8908	1.1224	1.3476	0.209831
A4	1.2009	1.1224	1.00	1.00	1.1224	1.00	1.5128	0.2354
A5	1.1224	1	1.1224	0.8908	1.00	1.2009	1.3476	0.2098
A6	1.1224	1.1224	0.8908	1.00	0.8312	1.00	0.9327	0.1452
Total							6.4223	1.00

Test of Consistency

If the calculated rate of consistency is less than 0.1 then it indicated that it is sufficiently consistent. The following are steps to test the consistency:

Step 1: To Calculate Weights

Weighted Sum Vector (WSM):

1.00	0.50	0.33	0.33	0.50	0.50		0.07603		0.4621
2.00	1.00	0.50	0.50	1.00	0.50		0.123522		0.7805
3.00	2.00	1.00	1.00	0.50	2.00		0.209831		1.3155
3.00	2.00	1.00	1.00	2.00	1.00	×	0.2354	=	1.4851
2.00	1.00	2.00	0.50	1.00	3.00		0.2098		1.4582
2.00	2.00	0.50	1.00	0.33	1.00		0.1452		0.9537

From this we get the consistency vector. Round off this CV up to four decimal points. Now, each of the cells is divided by each other cell. For e.g., when 0.4621 is divided by 0.07603 of 1st row, we get 6.0802 as the answer and so on the calculations are carried out.

0.4621		0.07603		6.0802
0.7805		0.123522	=	6.3198
1.3155	÷	0.209831		6.2702
1.485		0.2354		6.3084
1.4582		0.2098		6.9504
0.9537		0.1452		6.5681

$$\alpha_{max} = \frac{6.0802+6.3198+6.2702+6.3084+6.9504+6.5681}{6}$$

$$=6.4161$$

Amount of Consistency Index (CI):

$$C.I = \frac{\alpha max - n}{n-1} \qquad n = \text{No. of attribute}$$

$$= \frac{6.4161-6}{6-1} = 0.08322$$

Consistency rate $C.R = \frac{\text{Consistency Index (C.I)}}{\text{Random Index (RI)}}$

$$= \frac{0.08322}{1.24} = 0.06711$$

The consistency ratio obtained is less than 0.10; therefore the scale values assumed earlier are correct. Our data collected regarding the materials and their properties is given below:

Alternative	**Explanation**
P1	3YSZ
P2	Mullite
P3	Al_2O_3
P4	NiCrAl
P5	MgPSZ
P6	YPSZ
P7	$CaZrO_3$
P8	$MgZrO_3$

	A1	A2	A3	A4	A5	A6
P1	21	11.5	2.12	640	0.29	5711
P2	30	5.2	3.3	950	0.25	2800
P3	30	9.6	1.8	775	0.26	3696
P4	90	10.3	3.88	764	0.27	7870
P5	46	10	1.8	650	0.23	5600
P6	11.29	10.9	1.4	620	0.25	5650
P7	87	11.5	14.6	698	0.21	4680
P8	86	8.01	15.3	650	0.20	5600
Obj.	max	max	Min	max	Min	min
Weight	0.07627	0.1234	0.2097	0.2394	0.2097	0.14541

Step 2: Normalization of Matrix

For maximization of the objective function:

$$N_{ij} = r_{ij} / r_j^* \text{, i = 1 to 8 and j = 1 to 6}$$

And for minimization of the objective function:

$$N_{ij} = r_j^{min} / r_{ij} \text{, i = 1 to 8 and j = 1 to 6}$$

	A1	A2	A3	A4	A5	A6
P1	0.233	1	0.6603	0.6736	0.8	0.4902
P2	0.344	0.460	0.4242	1	0.8	1
P3	0.344	0.834	0.78	0.8157	0.7692	0.7575
P4	1	0.895	0.3608	0.8042	0.7407	0.3557
P5	0.511	0.8695	0.78	0.6842	0.8695	0.5
P6	0.125	0.9478	1	0.6526	0.8	0.495
P7	0.967	1	0.0959	0.7347	0.9523	0.585
P8	0.956	06954	0.0915	0.6842	1	0.5

Step 3: Multiply Attributes Value with its Respective Weight.

The simple additive weighting method evaluates each alternative, Ai. By the following formula:

$$A_i = \Sigma W_j x_{ij,}$$

where x_{ij} = value of the ith alternative w.r.t. the jth attribute,
W_j = weighted attribute,
i = 1 to 6 and j = 1 to 8.

The final matrix is as follows:

	A1	A2	A3	A4	A5	A6
P1	0.0177	0.123481	0.1384	0.1585	0.1677	0.0712
P2	0.0262	0.0568	0.889	0.2354	0.1677	0.14541
P3	0.262	0.1030	0.1635	0.192	0.1613	0.1101
P4	0.0762	0.1106	0.0765	0.1893	0.1553	0.0517
P5	0.0389	0.1073	0.635	0.1610	0.1823	0.0727
P6	0.0095	0.1170	0.2097	0.1536	0.1677	0.720
P7	0.0737	0.1234	0.0201	0.1729	0.1997	0.0851
P8	0.729	0.086	0.0191	0.1616	0.2097	0.0727

The summation of the attributes with their rank is as follows:

Alternative	**Summation**	**Rank**
P1	0.6769	5th
P2	0.07201	4th
P3	0.9937	1st
P4	0.6587	7th
P5	0.7257	3rd
P6	0.7295	2nd
P7	0.6749	6th
P8	0.6220	8th

Thus the best suited material obtained is P3, i.e.; **Alumina**

4. CONCLUSION

In this paper, we have explained the MADM method for selection of material. By the application of this method, the best suited material obtained is P3, i.e.; Alumina. With the use of simple software, the calculations could be speed up. The drawback of the method is that some attribute might have a qualitative property or have an uncertain structure which might be difficult to measure.

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