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Use of Analytical Hierarchy Process for the Selection of Optimum Parameter of IC Engine

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Abstract - *The Analytical Hierarchy Process (AHP) was introduced by Thomas L. Saaty in 1977 and 1994. The AHP is the decision making approach mainly based on mathematics and psychology. The AHP can be used to solve complex problems which involve multi – criteria. Input data required for AHP is easy to obtain, due to this reason most of the researchers get attracted towards AHP for the solution of their problems. It uses a multi – level hierarchical structure of objectives, criteria, sub criteria and alternatives.*

Keywords: Analytical Hierarchy Process, AHP, IC engine, engine performance

1. INTRODUCTION

AHP can be used in various fields like healthcare, business, government, education. AHP do not suggest a particular decision, but provides the one solution that best suits their goal. AHP can also be used for particular application in group decision making. AHP is a multiple criteria decision making (MCDM) or multiple criteria decision analysis (MCDA) tool. These tools are concentrated on structuring and solving the complex problems having multiple criteria (or multiple solutions). Typically, there does not exist a unique optimal solution for such problems and multiple criteria decision making (MCDM) or multiple – criteria decision analysis (MCDA) helps in choosing the "best" alternative from a set of available alternatives i.e. the most preferable one.

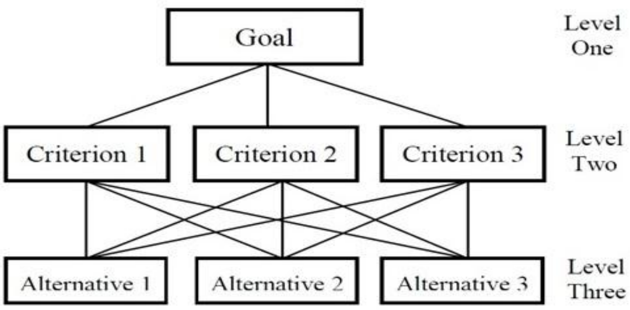

Figure 1.1 Sample hierarchical tree

1.1 Literature review

[1] Vincent H. Wilson et al conducted study on to optimize the control parameters of the direct injection (DI) single cylinder diesel engine with respect to NOx (Oxides of Nitrogen) and fuel emissions through experimental investigations and Taguchi method. A single cylinder 5.2 kW diesel engine was selected for this experiment. Five parameters such as clearance volume, valve opening pressure, nozzle-hole diameter, static injection timing and load torque were varied at four levels and the responses such as NOx emissions and fuel economy were recorded. The optimum values of the response variables could be predicted using S/N ratio and optimum combination of control parameters were specified.

[2]Chedthawut Poompipatpong, Athakorn Kengpol et al conducted study on various engine sizes and operating conditions. The objective of this research is to weight the frequently used engine parameters, which helps researchers to make a better decision under multi-criteria situation. The engine parameters are classified into three groups and weight by the integrated AHP-Delphi method, which converts opinions into numerical values. Moreover, it can deal with a group decision making to obtain the consensus of specialists.

[3] S.Arunprasad1, T.Balusamy et al conducted study on to optimize the engine parameters by using biodiesel as a fuel. Neem oil is used as a bio diesel in CI engine which is produced by Tran's esterification process. Taguchi optimization technique was used to get optimum level of parameters such as brake thermal efficiency (BTHE), indicated thermal efficiency (ITHE) and specific fuel consumption (SFC). Experiments were conducted with neem oil biodiesel blends and diesel value was compared with these results.

[4]G. Sakthivel a, M. Ilangkumaran, Aditya Gaikwad et al conducted study on application of hybrid Multi Criteria Decision Making (MCDM) technique for the selection of optimum fuel blend in fish oil biodiesel for the IC engine. Evaluation of suitable blend is based on the exploratory analysis of the performance, emission and combustion

parameters of the single cylinder, constant speed direct injection diesel engine at different load conditions.

[5] Abdel Rohman AI-Shabeeb et al conducted study to identify the potential sites for wind turbine in the study. The Qnalytical Hierarchy Process was used to identify the potential sites. According to writer importance of each criterion was based on the expert's opinion.

[6]Geetha N.K, Bridjesh P et al conducted study to find the optimal combination of operating parameters of a diesel engine. The proposed analytical hierarchy process not only provides the analysis of the alternatives, but also enables the visualization of various criteria present and their interrelations. The measures of the criteria and their relative importance are used to rank the alternatives. The use of permanent concept helps in better appreciation of the criteria and it characterizes the considered selection problem as it contains all possible structural components of the criteria and their relative importance.

[7] Warke Vivek Ramesh1, G. Sakthivel et al conducted study on to identify the apt fuel blend using FAHPPROMETHHE. FAHP method is applied to find the relative weights of the criteria, while PROMETHEE has been used to identify the best alternatives. NOx, Smoke, HC, CO, CO2, BTE, EGT, ID, CD and MRPR were considered as the assessment criteria. From the results, it is observed that B20 is the best blend.

[8] C. M. Sivaraja, G. Sakthivel, and Vivek Ramesh Warke et al conducted study on to identify the apt fuel blend using hybrid Multi Criteria Decision Making (MCDM) with various evaluating criteria and the alternatives. FAHP with TOPSIS and PROMETHEE are hybrid MCDM methods that are used to evaluate the suitable blend. FAHP is applied to find the relative weights of the criteria, while PROMETHEE and TOPSIS are used to identify the best alternatives. The performances of the MCDM methods were also analyzed with each other. A four-stroke single cylinder, constant speed, direct injection with a rated output of 4.4 kW was used for exploratory analysis.

[9]Edmundas Kazimieras Zavadsk, Audrius Cereska et al conducted study on new way of tackling transport pollution. The analysis of the energy ecological parameters of the experimental internal combustion engine is performed using the neutrosophic multi-objective optimization by a ratio analysis plus the full multiplicative form (MULTIMOORA) and step-wise weight assessment ratio analysis methods. The application of MCDM methods provides us with the opportunity to establish the best alternatives which reflect the best energy ecological parameters of the internal combustion engine.

[10]V Naveen Kumar, R S Pranav Raja, K S Sanjeevi, S P Anbuudayasankar and S Srihari et al conducted study on the engine selection for three purposes. Most influencing 10 parameters of each purpose have been shortlisted with the help of experts in the respective field. Then the parameters are ranked with the help of Analytical Hierarchy Process (AHP). It helps to prioritise the parameters while selecting an engine for specific purpose. In AHP the relative matrix is formed by using pairwise comparison with the help of experts then the relative matrix is squared and eigen vector is found. The eigen vector is used to rank the parameters and is reported as per the priority for the respective purpose. [11]Bolade R.S., Katkar M. M et al conducted study on Selection process in various fields. The various MCDM Tools used for selection process are AHP, GENETIC Algorithm, Fuzzy Logic and Fuzzy AHP and FEA. After reviewing the different papers it is found that AHP is a Simple and most effective tool for selection process. Among the various optimization methods most of the researchers used the Analytical Hierarchy Process for optimization. Also Author suggested that the AHP Tool can be used in future in any field for Optimization & selection process.

2. METHODOLOGY

A tool for managing qualitative and quantitative multi – criteria problems is developed by saaty. The working of this tool is based on a hierarchical structure and it also involves decision making. This tool is named as analytical Hierarchy Process (AHP)
Steps to be conducted while using analytical Hierarchy Process (AHP) are as follows
Step – I: Define the problem and find out final goal that is to be achieved.
Step – II: Arrangement of sample hierarchical tree with three levels, goal at top level followed with all criteria and at the extreme bottom level i.e. at the third level all possible alternatives are arranged.
Step – III: After all this arrangement a pairwise comparison matrix is formed. For preparing pairwise comparison matrix, a proper questionnaire should be designed and distributed among app the respondents.
Step – IV: Results obtained from pairwise comparison matrix are used to set weightage of each element considered.
Step- V: Check the consistency of judgment.
Step – VI: Final decision based on percentage of weightage.
AHP can be used in various disciplines hence, applying it for the selection of optimum parameter for increase in the engine performance. Engine performance is based on various values some of them are brake mean effective pressure, Engine torque, Cylinder swept volume, Compression ratio. The values for engine performance is mainly depend on the engine parameters some of the important engine parameters are bore diameter, stroke length, compression ratio, swept volume and etc. All these engine parameters can be used as criteria for analytical Hierarchy Process (AHP) problem. So, ultimate goal is to find out optimum parameter which enhances the performance of I. C. Engine.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

Table 2.1 Scale of relative importance by satty (1980)

The different alternative used is cylinder diameter, stroke length, swept volume and compression ratio. The various values recorded as the dimensions of all above criteria can be used as the alternatives for the hierarchical tree. All these things can be simply shown in the below AHP tree diagram

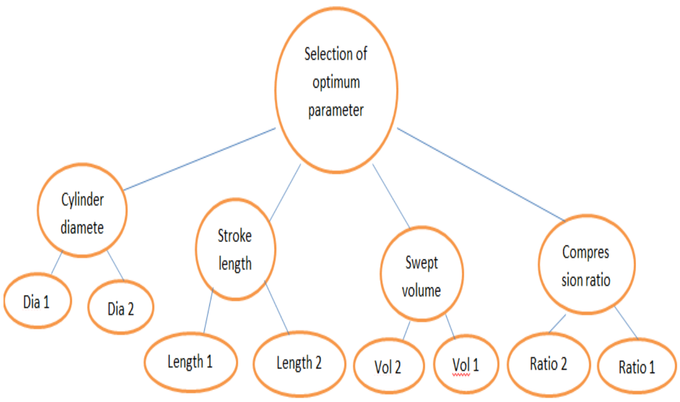

Figure 2.1 Hierarchy Tree for Selection of Optimum Parameter

Intensity of importance is assigned on the basis of weightage given to the importance of that criterion in increasing the engine performance. If higher diameter gives more engine performance than higher length then higher intensity of importance is assigned to diameter as per its weightage.

Step-I pair wise matrix

	Cylinder diameter	Stroke length	Swept volume	Compre ssion ratio
Cylinder diameter	1	5	4	3
Stroke length	1/5	1	3	4
Swept volume	1/4	1/3	1	2
Compression ratio	1/3	1/4	1/2	1

Step=II summation of all the columns

	Cylinder diameter	Stroke length	Swept volume	Compr ession ratio
Cylinder diameter	1	5	4	3
Stroke length	1/5	1	3	4
Swept volume	1/4	1/3	1	2
Compressi on ratio	1/3	1/4	1/2	1
sum	1.78	6.58	8.5	10

Step-III generation of normalized pairwise matrix

	Cylinder diameter	*Stroke length*	*Swept volume*	*Compres sion ratio*
Cylinder diameter	*0.56*	*0.75*	*0.47*	*0.3*
Stroke length	*0.11*	*0.15*	*0.35*	*0.4*
Swept volume	*0.14*	*0.05*	*0.11*	*0.2*
Compression ratio	*0.18*	*0.037*	*0.05*	*0.1*

Step-IV calculating criteria weights

	Cylinder diameter	Stroke length	Swept vol	Compression ratio	criteria weights
Cylinder diameter	0.56	0.75	0.47	0.3	0.52
Stroke length	0.11	0.15	0.35	0.4	0.25
Swept volume	0.14	0.05	0.11	0.2	0.12
Compression ratio	0.18	0.037	0.05	0.1	0.09

Step –V calculating consistency

	Cylinder diameter	Stroke length	Sweep volume	Compression ratio	Weighted sum value
Cylinder diameter	0.291	0.187	0.056	0.027	0.561
Stroke length	0.057	0.037	0.042	0.036	0.172
Swept volume	0.072	0.012	0.013	0.018	0.115
Compression ratio	0.093	0.009	0.006	0.009	0.117

Step-VI calculating weighted sum value

	Cylinder diameter	Stroke length	Swept volume	Compression ratio	Weighted sum value
Cylinder diameter	0.291	0.187	0.056	0.027	0.561
Stroke length	0.057	0.037	0.042	0.036	0.172
Swept volume	0.072	0.012	0.013	0.018	0.115
Compression ratio	0.093	0.009	0.006	0.009	0.117

Step-VII Finding ratio of weighted sum value & criteria weights

	Cylinder diameter	Stroke length	Swept vol.	Compression ratio	Weighted sum value	Criteria weight	ratio
Cylinder diameter	0.291	0.187	0.056	0.027	0.561	0.52	10.7
Stroke length	0.057	0.037	0.042	0.036	0.172	0.25	0.688
Swept volume	0.072	0.012	0.013	0.018	0.115	0.12	0.958
Compression ratio	0.093	0.009	0.006	0.009	0.117	0.09	1.3

λ_{max} = (sum of ratio's column /4)

= (10.78+0.688+0.958+1.3)/4

=13.72/4

= 3.431

Consistency index

(C.I= (n- λ_{max})/ (n-1))

= ((4-3.431)/ (4-1))

= 0.18

Consistency ratio =CI/RI

=0.18/2

=0.09

As consistency ration is < 0.10

All the criteria weights can be used for decision making

3. RESULTS

Parameter	Criteria weights
Cylinder diameter	0.52
Stroke length	0.25
Swept volume	0.12
Compression ratio	0.09

4. CONCLUSION

The calculation provides percentage criteria weights for different Engine parameters. According to these values, the most of percentage weight is distributed among cylinder diameter and stroke length. Hence, the Engine performance is mainly depends on the values of cylinder diameter and stroke length.

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BIOGRAPHIES

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