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Performance Optimization of Diesel Engine with Chicken Waste Bio-diesel Blend Using Grey Rrelational Aanalysis

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Abstract:- This paper presents an experimental study that include an application of the grey relational analysis to determine the optimum factor level to obtain optimum multiple-performance characteristics of a diesel engine run with different low-percentage chicken waste biodiesel-diesel blends. Grey relational analysis is used for data analysis and four factors, namely, low-percentage chicken waste biodiesel-diesel blend, compression ratio, injection timing and injection pressure were each considered at four levels. An L16 orthogonal array was used to collect data for various engine performance related responses under constant engine loads. Results of confirmation tests showed good agreement with predicted quantities. The results of the study revealed that the combination of a blend consisting of 10% chicken waste biodiesel (B10), a compression ratio of 18, an injection pressure of 220 bar and an injection timing of 19° bTDC produces maximum multiple performance of the diesel engine**.**

Keywords:- Compression ratio, Injection pressure, Injection timing, Chicken waste bio-diesel, Grey relational analysis.

I. INTRODUCTION

Various researches are striving for the best alternate that improves the fuel economy of an internal combustion (IC) engine. The demand and availability for petroleum fuels are somewhat unbalanced and there is a need to balance. If this situation continues, then the scenario will be more disastrous as petrol and diesel will be more costly and rare to obtain. With increased use and the depletion of fossil fuels, today more emphasis is given on alternate fuels. Most of the alternate fuels used today are biodiesel or bioethanol, which can be used in existing engines. The primary advantage of bio fuel is that they are renewable and eco-friendly. When biodiesel is used as a substitute for petro-diesel, it is highly vital to understand the parameters that affect the combustion phenomenon which will in turn have direct influence on thermal efficiency and emission. In the present energy scenario, lot of efforts are being focused on improving the thermal efficiency of IC engines with reduction in emissions. Many innovative technologies are developed to tackle this. Modification is essential in the existing engine designs. Some optimization method has to be tracked with the performance of the engine not comprised. As far as the internal combustion engines are concerned the thermal efficiency and emission are the important parameters for which the other design and operating parameters are to be optimized. The major optimization techniques used for engine analysis are response surface method, grey relational analysis, non linear regression, genetic algorithm and Taguchi method.

Researchers already studied the optimization of diesel engine performance and operating parameters using different techniques [5] like taguchi method, Matlab, artificial neural network etc. These methods are computationally efficient for optimization requiring hundreds of function calculations, and it saves cost and time in developing new replicas and methodologies for overall engine running [6]. Some work has revealed that, for analyzing complex problems of emission analysis of biodiesel and their blends, grey relational analysis is suitable, adaptable and flexible computing tool that can be used for analytic purposes [10].

From the work by Selva Ilavarasi Panneerselvam, Krish T Bharat et al. [14, 15], chicken waste can be used for the production of biodiesel. Waste chicken is harmful for human health due to fat content in the chicken. The large amount of chicken fat that is wasted can be used for the production of chicken fat based biodiesel. After production, it is necessary to check various chemical properties of biodiesel to see whether these are within limit or not [17]. For the production, transesterification process is mainly used. There are various catalysts that can be used in the production of chicken fat based biodiesel [16].

II. GREY RELATIONAL ANALYSIS

Grey relational analysis as proposed by Deng in 1989 is widely used for measuring the degree of relationship between sequences by grey relational grade. It can be used to represent the grade of correlation between two sequences so that the distance of two factors can be measured separately. In the case when experiments are vague or when the experimental method cannot be carried out precisely, grey analysis helps to compensate for the shortcoming in statistical regression. Grey relation analysis is an effective means of analyzing the relationship between sequences with less data and can analyze many factors that can overcome the disadvantages of statistical method. It is applied by several researchers to optimize control parameters having multi-responses through grey relational grade.

The use of Taguchi method with grey relational analysis to optimize the operating process of selected variable compression ratio (VCR) engine with multiple performance characteristics includes the following steps:

- Identify the performance characteristics and operating parameters to be evaluated.
- Determine the number of levels for the process parameters.
- Select the appropriate orthogonal array and assign the operating parameters to the orthogonal array.
- Conduct the experiments based on the arrangement of the orthogonal array.
- Normalize the experimental results of brake thermal efficiency (BTHE) and sp. fuel consumption (SFC)
- Perform the grey relational generating and calculate the grey relational coefficient.
- Calculate the grey relational grade by averaging the grey relational coefficient.
- Analyze the experimental results using the grey relational grade and statistical ANOVA.
- Select the optimal levels of operating parameters.
- Verify the optimal operating parameters through the confirmation experiment.

A. *Data Pre-Processing*

In grey relational analysis, when the range of the sequence is large or the standard value is vast, the function of factors is ignored. However, if the factors goals and directions are different, the grey relational might produce improper results. Therefore, one has to pre-process the data which are related to a group of sequences, which is called 'grey relational generation'. Data pre-processing is a process of transferring the original sequence to a similar sequence. For this purpose the experimental results are normalized in the range between one and zero. Normalization can be done form three different approaches.

If the target value of original sequence is infinite, then it has a characteristic of "the larger-the –better". The original sequence can be normalized as follows.

$$X_i{}^*(k) = \frac{[X_i{}^0(k) - \min X_i{}^0(k)]}{[max\, X_i{}^0(k) - min\, X_i{}^0(k)]} \quad \ldots\ldots\ldots.. (1)$$

If the expectation is the smaller-the better, then the original sequence should be normalized as follows.

$$X_i^*(k) = \frac{\max X_i^0(k) - X_i^o(k)}{max\, X_i^0(k) - min\, X_i^0(k)} \quad \ldots\ldots\ldots\ldots (2)$$

However, if there is a definite goal value to be achieved, the original sequence will be normalized in the form.

$$X_i^0(k) = 1 - \frac{|X_i^0(k) - X^0|}{max\, X_i^0(k) - X_i^0} \quad \ldots\ldots\ldots\ldots. (3)$$

Where, $X_i^*(k)$ is the value after data pre-processing.

$maxX_i{}^0(k)$ is the largest value of $X_i{}^0(k)$

$minX_i{}^0(k)$ is the smallest value of $X_i{}^0(k)$

Following data pre-processing, a grey relational coefficient is calculated to express the relationship between the ideal and actual normalized experimental results. They grey relational coefficient can be expressed as shown in the following equation.

$$\varepsilon_i(k) = \frac{\Delta_{min} + \varepsilon\Delta_{max}}{\Delta_{0i}(k) + \varepsilon\Delta_{max}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, $\Delta_{0i}(k)$ is the deviation sequence of the reference sequence $X_0^*(k)$ and comparability sequence $X_i^*(k)$

After obtaining the grey relational coefficient, generally take the average of the grey relational coefficient as the grey relational grade. The equation of grey relational grade,

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \varepsilon_i\,(k) \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Table I: Setting Levels for Design Parameters

Controlled factors	Level 1	Level 2	Level 3	Level 4
Compression ratio	12	14	16	18
Injection pressure (bar)	200	210	220	230
Injection timing (°bTDC)	19	20	21	22
Fuel fraction	5	10	15	20

Table II: Design Array and Observations

Sl no:	Compression ratio	Injection pressure (bar)	Injection timing (°bTDC)	Fuel fraction
1	12	200	22	5
2	12	210	21	10
3	12	220	20	15
4	12	230	19	20
5	14	200	21	15
6	14	210	22	20
7	14	220	19	5
8	14	230	20	10
9	16	200	20	20
10	16	210	19	15
11	16	220	22	10
12	16	230	21	5
13	18	200	19	10
14	18	210	20	5
15	18	220	21	20
16	18	230	22	15

III. EXPERIMENTATION

The experimental setup contains a single cylinder, four stroke, VCR diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be varied without stopping the engine and without changing the combustion chamber geometry by specially designed tilting cylinder block arrangement. The arrangement has a panel box consisting of air box, two fuel tanks for duel fuel test, manometers for air, fuel flow measurements and fuel measuring unit. The setup allows study of VCR engine performance for brake power, thermal efficiency, mechanical efficiency, volumetric efficiency and specific fuel consumption. For on line performance evaluation, a Labview based Engine Performance Analysis software package “EnginesoftLV” is provided. The setup includes a computerized diesel injection pressure measurement.

A. *Experimental Observations*

By employing the experimental design, 16 set of observations were made. The responses are measured by using "EngineSoftLV" software setup. The data collected during experiments are shown in table III.

Table III: Experimental Observations

Sl no	Compression ratio	Injectionpressure (bar)	Injection timing (° bTDC)	Fuel fraction	Brake thermal efficiency (%)	Specific fuel consumption (kg/kWh)
1	12	200	22	5	0.30	29.04
2	12	210	21	10	0.10	100.36
3	12	220	20	15	0.14	89.50
4	12	230	19	20	0.12	96.15
5	14	200	21	15	0.25	58.89
6	14	210	22	20	0.22	39.01
7	14	220	19	5	0.42	20.34
8	14	230	20	10	0.40	33.24
9	16	200	20	20	0.41	20.89
10	16	210	19	15	0.38	35.65
11	16	220	22	10	0.56	15.23
12	16	230	21	5	0.38	22.32
13	18	200	19	10	0.34	25.37
14	18	210	20	5	0.20	42.91
15	18	220	21	20	0.55	15.60
16	18	230	22	15	0.60	22.45

B. Data Analysis

1) ***Grey relational analysis:*** In the grey relational analysis, experimental data of the output responses are first normalized between the ranges 0 to 1. This process is known as grey relational generation. After normalization grey relational coefficient are calculated to express relationship between actual and desired experimental data. Then overall grey relational grade is calculated by averaging the grey relational coefficient of the output responses. The overall quality characteristic of the multi-objective process depends on the determined grey relational grade. Optimum process parameters are obtained using Grey relational analysis.

2) ***Data Pre Processing:*** The obtained data are pre-processed to obtain a normalized value. If the objective function required is maximization type (larger the better), equation 1 is used for pre- processing and if the objective function required is minimization type (smaller the better), equation 2 is used for data pre-processing. In this case for normalizing the BTHE data obtained, equation 1 is used and for normalizing the SFC data, equation 2 is used. The obtained pre-processed data are given in table IV.

3) ***Grey relational coefficient and grey relational grade:*** Following the data pre-processing, a grey relational coefficient is calculated to express the relationship between the ideal and actual normalized experimental results. The grey relational coefficient can be expressed as shown in equation 4. The obtained grey relational coefficient is given in table V.

After obtaining the grey relational coefficient, the average of the grey relational coefficient is taken as the grey relational grade. The grey relational grade obtained for each experimental run is given in table VI.

Table IV: Normalized Values of BTHE and SFC

Sl no	Brake thermal efficiency (%)	Specific fuel consumption (kg/kwh)	Normalized brake thermal efficiency	Normalized specific fuel consumption
1	0.3	29.04	0.4	0.837778
2	0.1	100.36	0	0
3	0.14	89.50	0.08	0.12757
4	0.12	96.15	0.04	0.049454
5	0.25	58.89	0.3	0.487137
6	0.22	39.01	0.24	0.720663
7	0.42	20.34	0.64	0.939974
8	0.4	33.24	0.6	0.788441
9	0.41	20.89	0.62	0.933513
10	0.38	35.65	0.56	0.760132
11	0.56	15.23	0.92	1
12	0.38	22.32	0.56	0.916716
13	0.34	25.37	0.48	0.880888
14	0.2	42.91	0.2	0.67485
15	0.55	15.60	0.9	0.995654
16	0.6	22.45	1	0.915189

Table V: Grey Relational Co-efficient of BTHE and SFC

Sl no	GRC brake thermal efficiency	GRC specific fuel consumption	GRC brake thermal efficiency	GRC specific fuel consumption
1	0.6	0.162222	0.454545	0.755033
2	1	1	0.333333	0.333333
3	0.92	0.87243	0.352113	0.364317
4	0.96	0.950546	0.342466	0.344698
5	0.7	0.512863	0.416667	0.49365
6	0.76	0.279337	0.396825	0.641571
7	0.36	0.060026	0.581395	0.892816
8	0.4	0.211559	0.555556	0.702683
9	0.38	0.066487	0.568182	0.882633
10	0.44	0.239868	0.531915	0.675796
11	0.08	0	0.862069	1
12	0.44	0.083284	0.531915	0.857215
13	0.52	0.119112	0.490196	0.807608
14	0.8	0.32515	0.384615	0.605951
15	0.1	0.004346	0.833333	0.991382
16	0	0.084811	1	0.854976

GRC - Grey Relational Coefficient

Table VI: Grey Relational Grade of BTHE and SFC

Sl no	GRC brake thermal efficiency	GRC specific fuel consumption	GRG
1	0.454545	0.755033	0.604789
2	0.333333	0.333333	0.333333
3	0.352113	0.364317	0.358215
4	0.342466	0.344698	0.343582
5	0.416667	0.49365	0.455159
6	0.396825	0.641571	0.519198
7	0.581395	0.892816	0.737106
8	0.555556	0.702683	0.629119
9	0.568182	0.882633	0.725408
10	0.531915	0.675796	0.603855
11	0.862069	1	0.931034
12	0.531915	0.857215	0.694565
13	0.490196	0.807608	0.648902
14	0.384615	0.605951	0.495283
15	0.833333	0.991382	0.912358
16	1	0.854976	0.927488

GRG - Grey Relational Grade

IV. RESULTS AND DISCUSSION

The grey relational grade graph plotted from this experiment is given in Fig 1. The level having highest grade value is chosen as the optimum parameter. The grey relational grade value for each parameter at various levels is obtained by taking the average of grey relational grade obtained from each parameter at each level. The grade values of different parameter at various levels are given in Table.VII.

The grey relational grades represented the level of correlation between the reference and comparability sequences. The larger grey relational grade means the comparability sequence exhibits a stronger correlation with reference sequence. Therefore, the comparability sequence has a larger value of grey relational grade for both BTHE and SFC. Based on this premise the study selects the level that provides the largest average response.

- In table VII, Optimum value occurred for compression ratio in 4^{th} level, for injection pressure in 3^{rd} level, for injection timing in 1^{st} level and fuel fraction in 2^{nd} level.

- The influence of each operating parameter can be more clearly presented by means of the grey relational grade graph. It shows the change in the response, when the factors go for their level 1 to level 4.
- The response graph for the operating parameters is presented in fig.1. In this figure, the greater values average grey relational grades give the maximum brake thermal efficiency and specific fuel consumption.

The Table VIII shows the confirmation result of the project.

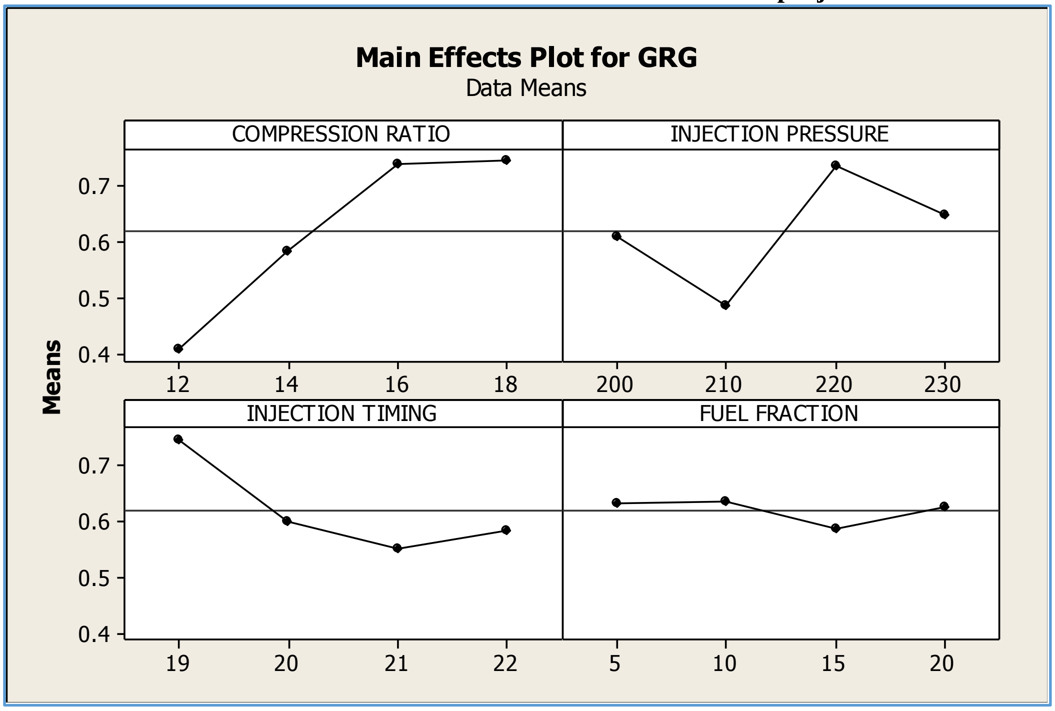

Fig. 1: Grey relational grade graph

Table VII: Grey Relational Grades for Parameters at Each Level.

Level	Compression ratio	Injection pressure	Injection timing	Fuel fraction
1	0.4100	0.6086	**0.7456**	0.6329
2	0.5851	0.4879	0.5989	**0.6356**
3	0.7387	**0.7347**	0.5520	0.5862
4	**0.7460**	0.6487	0.5834	0.6251

Table. VIII: Confirmation Test Result

Method adopted for optimization	Optimum value				Confirmation test result of Response variable	
	Compression ratio	injection pressure (bar)	injection timing (°bTDC)	fuel fraction	Brake thermal efficiency (%)	Specific fuel consumption (Kg/KWh)
Grey relational analysis	18	220	19	10	0.60	16.74

V. CONCLUSION

The chicken waste biodiesel is a social relevant alternate fuel. Nowadays, the chicken waste poses a serious damage to the surroundings by polluting both land and water. Proper disposal should be carried out. At the same time depletion of petro fuels and ever-increasing price of it is another concern. Connecting these issues, the single solution emerging is the production of biodiesel using chicken waste. The Grey relational analysis based on an orthogonal array of the Taguchi method was a way of optimizing the process parameters in engine process. The optimum operating condition was obtained when it works on the combination of a blend consisting of 10% chicken waste biodiesel and the remaining petro diesel (B10), a compression ratio of 18, an injection pressure of 220 bar and an injection timing of 19° bTDC producing maximum performance of the engine.

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