Response Surface Optimization of Chemical Additives and Engine Parameters on Performance Efficiency of Diesel Engine

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Abstract:

The findings revealed that, with the exception of ignition time, the impact of engine conditions on engine performance followed a similar behavioral pattern. 25 percent engine load, 20 percent hydrogen, 50 ppm MWCNTs, 220 bar ignition pressure, and 21 of TDC ignition timing were found to be the best settings for improved engine performance. Interestingly, the anticipated optimal engine performance was within 95% of the discovered optimal, however it did not fall within the testing runs that were taken into consideration. To clarify the effectiveness of the confirmation analysis, experimental work based on the discovered optimal settings is advised.

Keywords: Compression ignition, direct injection, Brake thermal efficiency, Brake specific fuel consumption, Hydrocarbons, Carbon monoxide, RSM, Taguchi Method, Optimization approach

This study used cashew shell oil and DIPE to present a brand-new Grey relational analysis with Taguchi technique model. The engine operating conditions for various injection pressures and timings can be improved and predicted using this model in the future [153–160]. For better combustion, 150 ppm of oxygenated DIPE was added to the same biodiesel blend as before. However, the braking thermal efficiency rises to 32.5% and the SFC value falls to 0.679 when the percentage of DIPE for various loads increases. (Yessian and Varthanan 2020)

In the study, when three input parameters were changed at once, an effort was made to optimize the engine reactions made up of eight separate parameters. Since the inquiry unmistakably suggested that a large number of test combinations were possible, the experiment was designed using the Taguchi method to reduce the number of experiments by creating an orthogonal array, but without losing important data. The responses were not unidirectional, which demonstrated the complexity of the optimization challenge. The weighting elements of grey relational analysis were then applied to the multi response problem to make it into a single problem, and the best solution was found using the test data.(Pohit and Misra 2013)

RESPONSE SURFACE METHODOLOGY OF EXPERIMENT

It's commonly used in the industry because it's the most effective technique for meeting welding requirements. This research looked at how to prepare low-cost goods and how to improve welding defects so that they work properly. This type of technique is commonly used to minimise costs and increase product quality, and it logs as functions of desired performance. Via rigorous design of experiments, the approach and variance in a process are minimised to aid in data interpretation and prediction of optimal outcomes. RSM is an effective modeling tool to establish a relationship between controllable input and their dependent output response. The studies concentrated on the modeling and optimization of combustion and thermal performance of the biodiesel in the dual-fuel engine through RSM are even rarer The following are the key RSM objectives and measures for the parameter design phase:

Choosing an experiment design and optimizing Based on literature survey, it has observed that Taguchi method is most easy and robust method. Also it is cost effective as it identifies the minimum number of experimental trials needed by suggesting correct combination of different design parameter needed for analysis of test results avoiding unnecessary data collection and their analysis. So Taguchi DoE has been used to identify the correct combination of selected design factor and their levels in present study. For the present study, factors and levels were selected based on literature review are mentioned in Table 4.

Factors and their levels.					
Symbol	Factors	Stage 1	Stage 2	Stage 3	Stage 4
A	Engine load (%)	25	50	75	100
B	Hydrogen (%)	0	10	20	30
C	Nanoparticles (ppm)	0	30	50	80
D	Ignition pressure (bar)	180	200	220	240
E	Ignition timing (0bTDC)	21	23	27	31

Table 4 Factors and their levels

Table: 4.3 L16 orthogonal arrays (Manigandan et al. 2020)

Engine Load	Hydrogen	MWCNT(ppm)	Ignition pressure (bar)	Ignition timing (°BTDC)
25	0	0	180	21
25	10	30	200	23
25	20	50	220	27
25	30	80	240	31
50	0	30	220	31
50	10	0	240	27
50	20	80	180	23
50	30	50	200	21
75	0	50	240	23
75	10	80	220	21
75	20	0	200	31
75	30	30	180	27
100	0	80	200	27
100	10	50	180	31
100	20	30	240	21
100	30	0	220	23

Optimization and Validation

Response optimizer is used to define a single response or combination of input variable settings that optimize a set of responses. In this study, the main purpose of optimization is to maximize BTE while simultaneously minimizing brake specific fuel consumption (BSFC), hydrocarbons (HC), nitrogen oxide (NOx), carbon monoxide (CO), and carbon dioxide (CO2).

Optimization criteria are shown in Table 5.5. The optimum engine operating parameters obtained from the optimization and the optimum BTE, brake specific fuel consumption (BSFC), hydrocarbons (HC), nitrogen oxide (NOx), carbon monoxide (CO), and carbon dioxide (CO2).values based on these parameters are shown in Fig. 5.13. On the left side of each response row in the optimization graph, there is the optimized response (y) and the individual desirability score (d) at the current variable settings. In the upper left corner is the compound desirability (D).

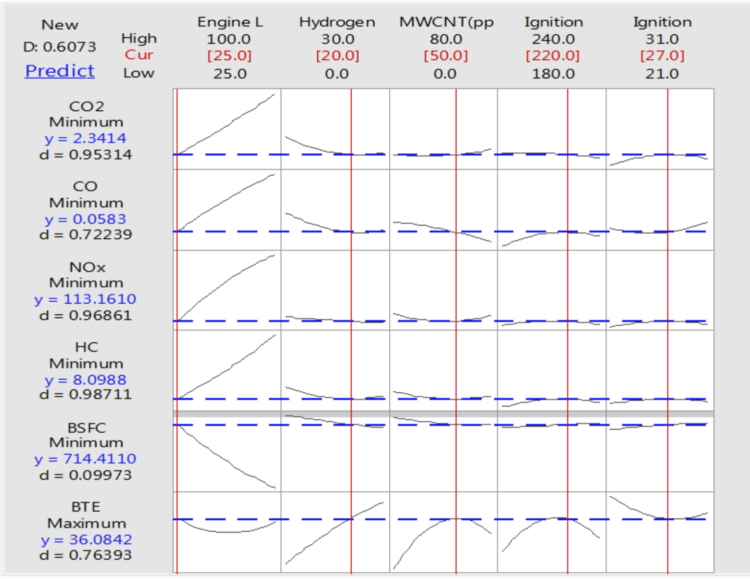

Fig. 5.13 Optimization results

These findings indicate that RSM models were found to be suitable to model and predict input parameters and performance and emissions of engine. RSM models developed for brake specific fuel consumption (BSFC), hydrocarbons (HC), nitrogen oxide (NOx), carbon monoxide (CO), and carbon dioxide (CO2). Emissions are experimentally verified, and the results were found to be within the tolerable error range. These methodologies can also be applied for other variables and a more holistic model can be developed.(Shunmugesh and Panneerselvam 2017)

Table: 9. Optimization criteria

Validation of RSM output response at 25% Engine load (%), 20% hydrogen, Nanoparticles 50 (ppm).220 (bar) ignition pressure and 31 Ignition timing (0bTDC),

Response	BTE	BSFC	hydrocarbons (HC)	nitrogen oxide (NOx),	carbon monoxide (CO)	carbon dioxide (CO2)
RSM response	36.0842	714.411	8.09	113.16	0.05	2.3414
Experimental	37.3	708	8	108	0.05	2.1
Error (%)	3.25	0.90	1.125	4.8	0	11.1

Percent Error =

$$\frac{V_{observed} - V_{true}}{V_{true}}$$

=

$$\frac{36.0842 - 37.3}{37.3}$$

=

$$\frac{-1.2158}{37.3}$$

= -3.2595174262734%= 3.2595174262734% error

The optimum values for BTE, BSFC, hydrocarbons (HC), nitrogen oxide (NOx), carbon monoxide (CO), and carbon dioxide (CO_2) are 36.0842,714.4110,8.09,113.16,0.0583 and 2.3414 respectively.

CONCLUSION AND FUTURE SCOPE

Hydrogen will likely play a significant part in the future of the transportation industry as a sustainable renewable energy source. This study was designed to look at how hydrogen and Nanoparticles affect the diesel engine's combustion and emissions. With a complete factorial design and 16 runs, the experiments are carried out by altering the engine load, hydrogen fraction, Nanoparticles ratio, ignition timing, and ignition pressure.

1. The Taguchi approach includes predicting the ideal variables for increasing BTE, decreasing BSFC, and reducing emissions.

2. Verification of optimization findings is needed. Utilizing the ideal engine settings determined during the optimization study, an experimental study was carried out to confirm. The optimization's results are compared with experiment results.

3. The optimum values for Engine load (%), hydrogen, multi-walled carbon nano tubes (MWCNTs), ignition pressure, and timing as 25% Engine load (%), 20% hydrogen, Nanoparticles 50 (ppm).220 (bar) ignition pressure and 31 Ignition timing (0bTDC), respectively..

4. RSM models developed for brake specific fuel consumption (BSFC), hydrocarbons (HC), nitrogen oxide (NOx), carbon monoxide (CO), and carbon dioxide (CO_2). Emissions are experimentally verified, and the results were found to be within the tolerable error range. These methodologies can also be applied for other variables and a more holistic model can be developed.

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